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OF THE

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Incorporated in the Seventh Year of William IV.

PATRONESS . . HER MOST GRACIOUS MAJESTY THE QUEEN.
PATRON . . . HIS ROYAL HIGHNESS THE PRINCE OF WALES.

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PAPERS

READ AT THE

Royal Institute of British Architects.

SESSION 1870-71.

USUI CIVIUM, DECORI URBIUM.

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Royal Institute of British Architects.

SESSION 1870-71.

OPENING ADDRESS by the President, Thomas Henry Wyatt, Esq.

At the Ordinary General Meeting of the Royal Institute of British Architects, November 7th, 1870.

Gentlemen,—There are few of the duties connected with the honorable position in which you have so generously placed me, that I approach with more misgiving than the one I now assume. An "Opening Address" on the occasion of our meeting after the autumn recess, seems to have become an actual *Institution*, to which every President must bow. And yet what can he tell yon that has the charm of novelty? I might almost say of information? In these days, with the weekly issue of able and illustrated papers of professional and general interest, the progress and completion of every great architectural work in the United Kingdom and our Colonies (if not in Europe), are so clearly and fully described, or so vividly illustrated, that we seem to know them almost as intimately as though they were our own children and our own efforts. With a considerable amount of ability, with some license, and with the bias which the adopted style invariably carries with it, their merits or demerits are freely canvassed. I can therefore tell you little of the great architectural works of the present day, which you do not probably know already, though I shall be tempted hereafter to enumerate a few of those going on in our own land, to show the vitality and energy of our age.

What fresh light can now be thrown on that hackuied subject, "the battle of the styles," a feud happily at present lying dormant, not to be revived, I trust, till the overpowering merit of some *future* work in one style or the other, shall give fresh light to the subject, and justify its followers and admirers in renewing the controversy.

What can I add to the eloquent and interesting appeals which have been made to you by my honoured predecessors on the noble and elevating nature of our profession—on the claims which it has to the consideration and interest of our *educated* countrymen, or on the necessity for diligent study on the part of its junior members and watchful thought and enquiry amongst its older followers, and though last not least, on the value of unimpeachable honour and equity amongst all.

Gentlemen, this does not complete the list of *my* difficulties and misgivings. I have to follow such men as Professors Cockerell and Donaldson, deeply read in the history and practice of our art, accustomed to teach and to lecture with facility. I follow Mr. Beresford Hope and Sir William Tite, men of large experience and fortune, with parliamentary position and influence, and with every facility of speech. Gentlemen, that I have to undergo this ordeal is your own act, and on your heads must fall the penalties of my shortcomings. I believe I shall act most wisely in following the *practical* examples of my predecessors rather than indulging in their imaginative or artistic disquisitions, in dwelling briefly on the progress and condition of the Institute; on its associated interests with other kindred societies, and on the leading architectural works of the day, and I shall offer some suggestions on two or three points of interest in our profession.

As far as numbers and income are concerned, our position with reference to past years may be said to be fairly satisfactory:

In 1869 we had	...	...	...	...	265 Fellows.
In 1870 we have	...	...	...	...	275 „
In 1869 we had	...	...	...	...	241 Associates.
In 1870 we have	...	...	...	...	243 „

(Several Associates have recently passed up into the Class of Fellows.)

In the list of Honorary Fellows, Honorary Members, Honorary and Corresponding Members and Contributing Visitors there is little difference.

In 1869 we had on our books only 5 Students. In 1870 we have 7.

It is a matter of regret that, with reference to this class, the efforts of the Council have not been successful. It is one which they are in every way anxious to encourage. The advantages are, we believe, considerable—the subscription very moderate; and yet, in proportion to the number of young men engaged in the offices of metropolitan architects, the result is discouraging.

I may here say how cordially I share the opinions of my predecessor, Mr. Beresford Hope, as to the anomaly of being able (under our charter) to elect a President from the class of "Honorary Fellows," or persons unconnected "with any branch of building as a trade or business," whilst we are unable to do so from the class of "Honorary Members," or persons not being British Architects, "but being eminent for their works or scientific acquirements" (a class subsequently formed under the bye-laws of the Institute). How much simpler and more natural it would be if these two classes could be merged in one—"Men eminent for their works or scientific acquirements, not being British Architects or connected with any branch of building as a trade or business, and resident in the United Kingdom."

Our total numbers, including *all* classes, amount this year to 624. I cannot think this a very satisfactory result, compared with the Institution of Civil Engineers, which at this moment numbers a total of 1885 members, "all told," of which no less a number than 177 belong to the student class, as compared with our 7.

The relative number of students in these two institutions is certainly a matter calling for individual action on our part. In the President's address of 1863, my predecessor, Mr. Donaldson, dwelt at considerable length, and with much force, on the difficulties of the English student in architecture up to that time, and compared the advantages offered on the continent to the student. He then spoke of the efforts making and made to remove this blot. Most assuredly those efforts have not deteriorated up to the present hour, and I believe the result is most hopeful, taking into account the action of all the societies, though, on the face of the relative number of students in the Institution of Civil Engineers and our Institute, the result appears unsatisfactory.

The institution of the "Voluntary Examination Classes" has been of such comparatively recent date that it is difficult to speak with any confidence of its practical result. Since 1863, when it was established by the Institute, three members have passed in the "Class of Distinction," and, assuredly, the names of those gentlemen should be known and appreciated, viz., Messrs. Phèné Spiers, R. Bayne and T. Watson. Twenty have passed in the "Class of Proficiency," and three this year in the recently established "Preliminary Class." I believe it will be generally admitted that the Institute has, in this matter, "done its duty in the most liberal and effective manner, and is entitled to the gratitude of all "young men now entering the profession, or preparing to do so." I quote the words used by former Examiners in their report a few years ago, and I am sure you will agree with me that the well-directed labours of the Examiners and Moderators of the present year have increased that obligation, and have

deserved our thanks. It would be strange, indeed, if an institution like ours was indifferent to a scheme which practically tested the progress of that knowledge of the various arts and sciences connected with architecture, for the advancement of which this Institute was actually founded. The Examiners have so well described the objects of this scheme that I cannot do better than quote their own words— "The subject is now, however, better understood than it was: the system has been found to answer "so well with legal and medical men, with the soldier, the sailor and the diplomatist, with, in fact, "every rank where the education of a gentleman is expected, as well as the ability of the professional "man, that there seems little doubt that this Examination, if carried out with judgment and good feeling, must advance the 'British architect' in popular respect and in social position."

Dealing with finance (and excluding the noble contribution in 1868 of £500. by Sir William Tite to the Library) our position is as follows:—

In 1868 our receipts were	£1882	8	3
„ our expenditure was	1795	14	9
Balance	86	13	6
In 1869 our receipts were	£1951	19	5
„ our expenditure	1818	17	1
Balance	133	2	4

thus giving in the two years an average of £109. 17s. 11d. excess of income over expenditure, a margin shewing prudent caution on the part of your executive, but one with which flights of fancy or ambition are not to be indulged. It is only fair to say that, during the last year, a sum of £300. has been invested in the purchase of £321. 14s. 4d. of Consols out of "Ordinary Funds." In all cases the monies paid for "composition" by members have been duly invested. We have, moreover, recently made special donations of £50 towards the establishment of Architectural Art Classes, and £25 to the Architectural Museum. This liberality (and in a society with our limited income it may justly be so called), has, in addition to expenses of the Voluntary Architectural Examination, amounting to about £120., considerably diminished our resources, and will leave us but little balance in hand at the close of the present year.

This closeness of income to expenditure is, I think, in one respect, specially a matter of regret. One of your past Presidents said, some years ago, "We ought now to have a competent paid secretary, "whose whole time shall be at the service of the society. It was suitable to the early years of our "untried institution to depend on the gratuitous labour of honorary secretaries, but we have over-"grown such a mode of treatment." Gentlemen, I share this feeling fully, and so, I know, do many members of the Institute. It led, as you know, to the changes which took place about four years ago, and to the appointment of our present "assistant secretary." But when that appointment was made an impression existed, and I believe still exists, that, under our charter, we are bound to have two "honorary secretaries." This is, however, a mistake. There is not a word in the charter about their being "honorary." The charter simply states that there shall be two secretaries, and it is only one of our Bye-laws, passed in 1866, which provides that the "paid officers of the Institute shall be an assistant secretary, a clerk, and a librarian." But the same power that made this bye-law would enable us to change the office (now held by our accomplished Fellow, Mr. Eastlake), and to substitute for his present title the simple word "secretary."

It is too heavy a task to impose upon any architect engaged in the active work of his profession to take gratuitously, in addition, a labour oar in our work, not (as it has already been well said in this room) "the mere pleasurable occupations of an idle life of men of leisure, but precious moments, hours and days, stolen from absorbing professional avocations." As a general rule, the value of unpaid services and of divided duties is inconsiderable. In our case, up to this time, we have, fortunately, been an exception, but we should not forget that "the exception proves the rule;" and, before our meeting next May, before we again seek to impose similar labour on one of our working fellows, let us see if we cannot "so cut our coat" as to indulge in the luxury of one properly paid working Secretary, whose whole time shall be at our service. Happily for us, one of our body who has his whole heart and soul in the progress of our Society, has retired from the active duties of his former profession, and, as long as Professor Donaldson (than whom no man in the kingdom is better qualified for the post) will continue to discharge the duties of "Honorary Secretary for Foreign Correspondence," he will enable us to comply with the conditions of our charter, he will materially promote our interest and progress, and will, I believe, gratify every member of our body. In the Institution of Civil Engineers such an arrangement as that of a paid and an honorary secretary works most harmoniously and beneficially, and I cannot doubt it would do so in our case.

I now turn to our obituary. Happily our loss in numbers has not been very great since this time last year. Of Fellows, Mr. Burn, Mr. H. Garling, Mr. J. D. Hopkins, and Mr. J. W. Papworth, have passed from us. Herr Zocher, an Honorary and Corresponding Member, and Mr. Alley, an Associate, have to be added to the list. Professor Donaldson has already done full honour to Mr. Burn's career, and let me, who knew him well, be allowed to throw one chaplet on his grave. I have never known a man of higher or more independent honour than Mr. Burn; he was fearless in his assertion of what he believed to be just and right, and hence the almost unbounded confidence which his clients placed in him; such a list as few (if any) of our profession have ever owned. Mr. Garling and Mr. Hopkins were early members of the Institute, the former having been elected a Fellow in 1848, and having been a Member of Council; the latter elected in 1847. Mr. J. W. Papworth was elected a Fellow in 1846 and also served on the Council; he was for many years a most constant attendant at our meetings, one deeply interested in the welfare and advancement of the Institute, and not less deeply read in the practice, history, and literature of his profession; his professional career was so fully and so cordially described in the 'Builder,' that I will not weaken it by any remark of my own.

The supply of Papers for our ordinary meetings has always been a source of trouble and anxiety to your Secretaries, and the Council feels that the importance of this matter has not been fully shared by the members. Again do they venture to recapitulate all that has been said by your past Presidents on this subject, to urge the members to aid in this matter, and to remember that well-arranged descriptions of works of importance, superintended by individual members, may be most useful and interesting, as illustrating varied views and treatments of the same subjects, and frequently calling attention to the application of new materials and new appliances. The duty of procuring and selecting such Papers is now entrusted to a special Committee, consisting of Professor Kerr, Professor Hayter Lewis, and Mr. Wyatt Papworth.

The Council wishes further to remind members of the 29th Bye-law, which says that—"All members "whether Associates or Fellows are expected within twelve months after their election to deliver an "original paper to the Council on some subject connected with architecture, or to make a donation to "the library or collection." I think it will be acknowledged that these expectations of the "early fathers" of the Institute have not yet been fully realized, though in some instances the bye-law has

been interpreted and complied with in a very liberal manner. Money donations to the Library Fund, amounting to nearly £40. have been received during the Recess, and among them I have the pleasure of referring to the generous gift of twenty-five guineas from Mr. J. Humbert. On the other hand, we have been promised contributions, in the shape of Papers from our own members, Mr. B. Ferrey, Professor Austed, Mr. E. Salomons, Mr. H. Currey, as well as from Mr. W. H. Barlow, the eminent engineer, and from your humble servant.

During the last Session some interesting papers leading to useful discussion were read. Among them I may mention Mr. Street's most able and comprehensive treatise on "Some of the differences of Style in Old Buildings:" Mr. J. D. Crace's paper on "The Ornamental Features of Arab Architecture," a novel subject to many of us, ably introduced and attractively illustrated: Professor Donaldson's "On Autograph Drawings of the Great Masters of Architecture," and Mr. J. H. Parker's "On the Early History of Roman Architecture as illustrated by recently-discovered mural remains."

Let me now pass to another subject the consideration of which I cannot but think is one of great importance to our profession.

At this moment there are, I believe, in existence no less than eight societies, all more or less associated with objects connected with architecture and kindred to our own:—

1. The Institute.
2. The Architectural Association.
3. The Architectural Alliance.
4. The Architectural Museum.
5. The Architectural Exhibition.
6. The Architectural Benevolent Institution.
7. The Architectural Publication Society.
8. Architectural Art Classes.

Now, Gentlemen, if subdivision weakens, if a stream diverted into half-a-dozen different channels takes from the power of the original current, and if "union is strength," would it not be wiser and probably more successful if all these societies, working for ends tending to advance and benefit one profession, could be united and worked, if not under one management, at least, as one society, one powerful body? I am not the first of your Presidents who have felt that some effort might be made in this direction with advantage, and though I am probably treading on delicate ground, I cannot help feeling that it would only require time, patience, and tact, to realize a good deal of the object I have in view.

When a benevolent society was sought to be established by the Institution of Civil Engineers, it was not left to the individual action of one or two zealous and kind-hearted members only, as it was with ours. The matter was taken up by the Council of the Institution and a sum of £22,000. was raised in a few weeks, and its funds are administered by a committee of seven subscribers, of whom the President and two Members of Council are *ex-officio* members.

I am ashamed to confess that I do not know whether any attempts have hitherto been made to realize these objects, beyond those alluded to by Mr. Beresford Hope, with reference to the "Architectural Museum," but I cannot think there should be any serious obstacle to the union of three societies like the Institute, the Architectural Association, and the Architectural Alliance, whose objects are so similar, if the union was approached in a spirit of conciliation and mutual trust. This junction being realized, and suitable premises being obtained, the five societies last named might naturally find their home under one roof.

The Institute, consisting of 624 members, was founded "for the general advancement of civil architecture, and for promoting and facilitating the acquirement of the knowledge of the various arts and sciences connected therewith."

The Architectural Association, consists of 550 members, engaged professionally in the study

or practice of architecture, and of those interested in the various arts and sciences connected therewith, the Association dwelling specially on the importance and necessity of a more complete and systematic education of architectural students.

The objects of the Architectural Alliance, established about 1862, are to promote unity of action, and good feeling throughout the country at large, and to aid in improving all matters connected with professional practice, such as competitions, unity of professional charges, contracts and agreements with builders, &c. The Alliance now includes nine or ten other metropolitan and country societies, and appears to be in full action.

Here then are objects, surely, most closely united—the "Association" devoting its great and careful energies principally to the education of the students of architecture; and how successful their energies have been, and how deep an interest is taken by the younger members of our profession, by our assistants, and by the pupils of London offices, is shewn by the fact that, in the last year, 103 new members have joined the "Association."

Whilst on the subject of "unity of action," let me say a few words on the desirableness of that unity in the most comprehensive way and in all that affects our professional action: we have established a code of charges which is accepted generally by the profession throughout the kingdom as equitable and as its guide, and which has been recognized by some of the courts of law as fairly binding on employers and employed. Why should we not lay down one to be our guide in all matters of competition? (since competitions, in spite of their many inconsistent and unjust results, will probably still be resorted to); why not seek to aid by the power and influence of the Institute, the laudable exertions which have for some time past been made in this direction by the Architectural Alliance? Why not seek to form amongst ourselves a court of appeal for all questions of professional etiquette and conduct? Why not agree to certain general conditions of contract which may be recommended to the profession by the Institute as proving an equitable basis of contract between our employers and the builders engaged in their works? Your Council has had frequent meetings and discussions with the Committee of the Builders' Society, and has agreed upon certain general headings for conditions of contract between employers and employed, which it thinks equitable, and which will shortly be submitted to a General Meeting of the Institute for approval and adoption. They have been approved by the Committee of the Builders' Society, and I am informed that all the tenders lately submitted for the great work at the Government Offices, were made on the understanding that these general conditions formed the basis of their contract. I am glad to find that my predecessor, Sir William Tite, sanctioned with his experience the equity of having a reference or appeal from the decision of the architect on some points, though not of course on questions affecting the quality of the work or of the materials. The absolute power often claimed by some engineers and architects, of deciding all questions connected with the contract, and its intentions even, appears to me, contrary to every principle of equity, and though some may still cling to such powers, we have abundant proofs how painfully, and yet how ineffectually such powers work. We can all remember the lingering years of litigation and expense connected with the great case of Mackintosh *v.* the Great Western Railway Company, in which Mr. Brunel's decisions were disputed. The case of Smith and Knight *v.* Penarth Dock Company has been for years before the Courts, and is now hung up in Chancery in spite of Mr. Hawkshaw's powers under the contract, and Mr. McClean has been equally powerless to enforce his award in the case of Hill *v.* the South Staffordshire Railway, though his powers of decision appeared unlimited; this case has now been fourteen years in litigation. I believe that many engineers of the highest position are now in the habit of introducing arbitration clauses in their contracts, and that it is by no means unusual to nominate the President of the Institution of Civil Engineers for the time being as the

arbitrator between the engineer and contractor engaged on the work, or leaving it to him to nominate the arbitrator, an arrangement sanctioned by the solicitors of the various public bodies interested.

And, may I ask why there should not be one General Building Act applicable to all towns in England with a certain population (and with powers to enforce the provision of the Act), instead of having upwards of 200 corporations and local boards to introduce varied and conflicting regulations involving much uncertainty, and sometimes unnecessary trouble to the architect practising much in the country? The Town Council of Liverpool has postponed any amendment in its local Act, in the hope that Government may introduce one general Act. It surely would not be impossible to arrange one Building Act which should be sufficiently broad and comprehensive to meet the various conditions of materials and local customs, and sufficiently elastic to admit of the introduction of novel materials or of improved modes of construction.

If the vision I have indulged in of a real alliance amongst all these bodies is too visionary and hopeless, then, at least, let us have mutual sympathy and respect, and as far as possible co-operation. The success of any one of these bodies must aid in the great work we all have in view. The education and advancement of the architectural student and pupil is an object of as great moment to the architect as it must be to the interests of society. The formation of a student class by the Institute itself; the institution of Architectural Professorships at King's College and the London University; the various classes and courses instituted by the Architectural Association; the establishment of a Voluntary Architectural Examination; the Soane Medallion; the travelling studentship of the Royal Academy; the Pugin Travelling Studentship; all offer benefits to the architectural student and pupil of the present day to which we of a passing generation were strangers. They are to be largely congratulated on such advantages, and I trust there is little doubt that the future of our profession will proprotionately bring forth fruit. What such opportunities are doing for the *professional* student, for him who will hereafter have to earn his bread by his own hand and head, the establishment of the Fine Art Professorships at Oxford and Cambridge will, I hope, do for those studying in the Universities, and who from wealth and position naturally form the principal class of the architect's future employers. Hitherto, the study of art in any shape was, if not repudiated in the Universities, at least ignored; and I am sure there are many members now present who will bear me out in the assertion that some of our greatest professional difficulties and discouragements have arisen from a want of knowledge and sympathy with architecture itself, or with the other arts so intimately bound up with it amongst some of our employers. How then, is this drawback to be met? not by attempting to teach the non-professional world the details of design and construction, but by inducing all teachers to make the study of architectural history in its general features a portion of all liberal education. The history of the growth of architecture, like that of the other arts is, in fact, an essential element in the history of civilization and enlightenment, and is necessary to the formation of the thoroughly educated mind. The creation of each architectural style or period has been the result of the religious, political and social ideas, and of the mechanical appliances of the period which gave it birth. In every age which has produced a true style of its own, the principles of this creation have been the same, though the details and constructive forms may have differed, and it is just the knowledge of these principles of sound art, whether of architecture, painting, or sculpture, which it is desirable to teach the employer—the non-professional student. The study of architectural forms is thus a necessary element in the study of the history of the most civilized races of the world. The study of the literature of any nation is only one element in the acquisition of a knowledge of its real life, and to the study of its literature should be added the study of its arts as the expression of that life in visible forms. This, I venture to believe, would be the cure for the apathy and ignorance of some employers in matters of art, and it is as practical as it is urgent.

It may, indeed, be regretted that such studies did not form part of the education of that body of seven noblemen and gentlemen of the highest position in the country, who formed a commission, but a few years ago, to enquire into the deficiencies of the Royal Academy (a society formed to promote the three sister arts of painting, sculpture and architecture), and who, after sitting for months and hearing abundant evidence of the want of aid or instruction to the architectural pupil, made an elaborate report and various suggestions, but without giving the shortcomings affecting our profession "*one single word of notice or allusion.*" A very distinguished member of that academy called attention to this fact "as a proof of the little consideration which architecture received in this country at the hands of "those from whom it had a right to expect the very highest consideration."

If the Royal Academy, as a body, do not feel the importance of the study of architecture, we have, at least, on record, the wise and living words of their late President, Sir C. Eastlake, who said— "Viewed only as an academical study, no pursuit connected with the objects of taste can more fitly "recommend itself as an adjunct to a liberal education than a correct knowledge of architecture, and a "power of forming a sound judgment on the works of the architect;" but the Royal Academy, like all other public bodies, sooner or later, follows the current of public opinion. Only last week a new school was opened in the rooms of the Royal Academy, specially devoted to the study of architecture. I believe the members of the Academy deserve our thanks for this concession, tardy though it may be, as I think the architectural members of the Academy (with whom, I imagine, the appointment rested) merit especial praise for having selected as the future master, or director of this school, our member, Mr. Spiers, whose early career has been so brilliant, and who, from education, power and zeal is most admirably qualified to aid and direct the future students. The establishment of these classes ought to be universally known amongst our metropolitan students. Printed regulations and instructions will soon be issued, and I trust that every advantage may be taken of this boon, thus adding another to the several existing opportunities which the architectural student of the present day possesses for perfecting himself in the study of his profession.

Whilst on this subject it is not easy for an English architect to avoid dwelling on the little encouragement given in this country by its Government to the development and advancement of his profession, or (I was going to say) to the honor of its professors, but I have to remember that lately two of our body have been selected for such honor as the Crown confers on art, and that another member will, it is stated, be similarly complimented.

It has been asked "is *Imperialism* necessary for this?" I do not know that it is, but I do know that under Imperial rule in France, in Austria and in Russia even, far more is done towards such ends than in England, with all its boasted wealth and energy. What marvellous progress has been made in France under the strong will and ambition of its late ruler; an ambition to hand down to posterity his name in connection with the grandeur and beauty of his metropolis, with the embellishment of the great cities, and the restoration of the great historic monuments of his country, and, though misfortune and reverse are sitting heavily on his later years, his name will, in history, be held in honor for the encouragement he has given to the architecture and art of his great country.

Of the great public buildings in the Metropolis, now in progress or recently finished, I presume that the following may be classed as "National Works," undertaken by the Government and paid for by the country, viz.:—

1. The Foreign Office (the India Office being paid for from Indian Funds) and the Home and Colonial Offices, for which tenders have been lately submitted.
2. The London University Building in Burlington Gardens.
3. The completion of the South Kensington Buildings, commenced by Captain Fowke.
4. The Rooms for the Learned Societies in Piccadilly.

The "Albert Memorial," for which so large an amount has been raised by the subscription of individuals, from our Queen downwards; and the "Hall of Arts and Science," which may fairly be classed as a joint stock undertaking—important and costly works as they may be—can hardly be classed as "national works, undertaken by the Government and paid for by the country."

The "Law Courts," when realized, may, perhaps, come under that denomination, but they have shared the usual fate of Government works—procrastination and indecision, and have been bandied about from one commission or commissioner to another, from site to site, and from architect to architect; and, inasmuch as they will mainly be paid for by a fund which has accumulated from the suitors, I can hardly give Government credit for great liberality or energy in this matter. It has been truly said, elsewhere, "This affair of the Law Courts is discreditable to Government. It is an illustration of that "special characteristic of British officialism, which puts off everything until public opinion will wait no "longer, and then comes forward with crude and shallow propositions, trusting to Providence to bring "them to a happy issue, perhaps believing in competitions as a sort of providential arrangement for the "development of *unknown genius*." Happily we may at last believe that the site, the plans and the architect have been finally decided on, and that in the early spring we shall have evidence of more energetic action than is at present apparent. Let us seek to dismiss from our minds all questions of past dispute or delay. I have no doubt that the proper site has been at last fixed on, and as little, that this great work is in the hands of an accomplished and able artist, from whom we may fairly anticipate a result that will do honor to his name and credit to our profession.

That part of the Government Offices, comprising the Foreign and Indian Offices, are at last complete, and a new contract has lately been entered into for the completion of another portion, the Home and Colonial Offices. In this great work, timidity and indecision seem to have largely prevailed. The prize block plan for laying out the Government Offices (in the competition originated by Sir Benjamin Hall) has been disregarded, the new buildings seem to have no connection with the other public offices as regards style or position, they have been done piecemeal instead of dealing boldly and at once with the whole group, wasting money in the tenancy and occupation of inconvenient and detached offices now rented at heavy rates, and giving increased value to adjoining properties, which will ultimately have to be purchased.

The London University, in Burlington Gardens, has happily passed out of the category of "unfinished works." I am glad to have this opportunity of expressing my admiration of the way in which Mr. Pennethorne has carried out this work, where parsimony does not seem to have fettered its author, and where he has wisely and liberally brought to his aid the labor of the Sculptor. Gentlemen, the Institute, by its presentation of a Special Gold Medal to Mr. Pennethorne for his work at Somerset House, has already sought to do him honor. I feel sure there are none here who have not heard with pleasure that it is in contemplation by the Sovereign to add to his honors, and thus to mark the sense entertained by Government of the long and faithful services of this gentleman. May he live long to enjoy his repose and his laurels, his professional brethren will not forget the ready aid and courtesy that he always held at their disposal.

The South Kensington buildings and the group in Piccadilly are now making considerable progress, and it will only be right to wait for their completion before offering an opinion as to the result. Few of the passers-by through Piccadilly can be aware of the fact, that within the block of buildings that surround the old court of "Burlington House," on three sides there will be housed six important literary and scientific societies and a central post office:—the Royal, Geological, Chemical, Linnæan, Astronomical and Antiquarian Societies; all will be accommodated, a sort of "multum in parvo," and if the distinguished architects, who have had to arrange their plans, succeed in satisfying all these bodies, they will have accomplished a Herculean task In two years from this time we may hope to see the completion of this

important work, and I trust that the new tenants and the present occupants of Burlington House may long dwell together as a "happy united family."

There seems to be an indifference and apathy on the part of our rulers and our Parliament to aid in adorning the Metropolis, or to do for our profession that to which the rulers of Continental States attach such importance. Almost all is left to individual energy and liberality, and a spirit of parsimony reigns over the art administration of this country, as it seems to be doing in many other departments, and yet some allowance should be made for the Government of this representative and independent country. Here, London is but a spot in the political horizon—a mere atom of the wealth and energy of the kingdom. Manchester, Liverpool, Glasgow, Bolton, and Leeds, all claim their share in the power and government of the state. Far different is it in France where Paris is the sun, round which all their cities revolve and worship, and for the adornment and glory of which every Frenchman is (or rather was) prepared to make any sacrifice. I cannot better illustrate the difficulty the Chancellor of the Exchequer must feel in dealing with public funds for the adornment of London than in reading an extract from the letter of an accomplished and influential architect practising in one of our largest towns. I had applied to him for aid towards the funds for the restoration of St. Paul's Cathedral, he writes thus: "I hope the fund for the cathedral will be raised, but Parliament has done so much for "London at the cost of the country, that there is not much disposition in the provinces to subscribe for "London objects, even when, as in this case, one of national interest. The remark frequently made is, "the nation provides London with parks, museums, galleries and libraries, whilst in Manchester, "Liverpool, and other large country towns, we have to find them for ourselves. Let the ratepayers of "London do as much for themselves as we have to do for ourselves."

If this feeling exists in the mind of an accomplished and educated architect, fully alive to the beauty and influence of architecture, how much stronger must it be in the mere parliamentary representative, whose popularity is frequently in the inverse ratio to his intelligence and liberality, and with whom the Chancellor of the Exchequer has principally to deal. Thanks, however, to the strong will and generosity of individuals, our generation may, I think, be proud of what it has done and is now doing.

In our metropolis we have, at last, seen realized by the Metropolitan Board of Works a goodly instalment of that grand embankment scheme suggested by Sir Christopher Wren after the fire of 1666. His plan was actually ordered to be carried out by Act of Parliament 22nd Charles II; and, though scheme upon scheme, and committee upon committee have advocated and urged its being carried out, it was not until 1862 that it took a definite form, and the Act of the 25th and 26th Victoria has realized that which the Act of 22nd Charles II. failed to do. How ably Mr. Bazalgette has conducted this undertaking needs no praise from me. He has given us a noble work in which beauty and utility go hand in hand. Let us hope that the various vexed questions of "Approaches and Distribution of vacant spaces" connected with this embankment may be as successfully dealt with as has been the main work, and that the great pedestals, so evidently left for sculpture, may ere long be properly tenanted.

The Metropolitan Board of Works deserve also the thanks of all who care for the improvement of London, for having accomplished a work much needed, and which has been urged for twenty years, viz.; the removal of Middle Row. In 1865, an Act was obtained, and we are able now to appreciate this boon. Nor has the City of London been backward in the good works of improvement and utility. They have lately realized an admirable Meat Market, that has always formed part of the scheme for removing Smithfield. Plans had been prepared at various times, but it was not until 1865 that the design was finally approved, and the present City architect enabled to carry out a work which will associate his name with the history of that Corporation which he serves so well.

That body have further taken in hand and brought to a successful issue the internal decoration of their Guildhall; they have now in progress on an important scale, worthy of the City, a Museum and Library adjoining the hall, works on which their architect has to be complimented; but the great undertaking of the city authorities, that which has removed a standing disgrace to the city and added a great beauty to its public ways, is the realization of the Holborn Viaduct. One of the first advocates of this improvement was Mr. John Turner, an early member of this Institution. In 1833 he submitted a plan and model; and various plans were subsequently submitted by others. In 1848 a scheme was prepared for the city by Mr. Bunning, and in 1859 one by Mr. Marrable was authorized by the Metropolitan Board of Works. If "in a multitude of counsellors there is wisdom," then Gentlemen must the city be held very blameable for having allowed so many plans to drop, and so many years to pass before they ventured on this important work. At last, in 1863, a competition for plans was decided on, and the works were entrusted to the care of the Surveyor of City Sewers, Mr. Heywood. They were commenced in 1863, and completed in 1869, when the viaduct was opened by the Queen. As Members are aware, questions of a delicate nature have arisen as to the equity of that competition, and others even as to the stability of some part of that structure. I will, therefore, only say that we should be thankful for what we have got—a grand approach to the city, of the merit and stability of which I have, individually, no doubt.

The railway companies have contributed their share in the erection of the two large hotels at Charing Cross and Cannon Street, by our member, Mr. Edward Barry, and though last, not least, the Midland Railway Company have called to their aid the services of a distinguished Member of our body, and a noble pile of buildings is making rapid progress. I know no instance in this country in which the services of the engineer and architect appear to have been so thoroughly associated or to have realized such a happy result; and it is refreshing to see a case in which that almost universal bug-bear, economy, has not been allowed to interfere with and mar the whole; and this remark applies also to another great metropolitan work now near completion, certainly the largest and most important hospital that has been built in London on the pavilion principle. It is, I think, a fortunate thing for the importance and improvement of the metropolis that St. Thomas's Hospital has found a resting-place immediately opposite the Houses of Parliament, and that instead of that large river frontage being left to the mercy and the usual independent action of individual builders, or to the uncertainty, which once prevailed, attending the vacant ground adjoining the Northern Embankment, a public building of vast extent and importance, with varied outline and considerable architectural effect has been realized—one on which our member, Mr. Currey, has to be congratulated.

If, under the provisions of the "Metropolitan Asylum District Act" the various hospitals and infirmaries building by that Board, and paid for by a rate on the metropolis, cannot in justice to the ratepayers lay claim to *much architectural* pretension or ornament, their arrangements and details will, I trust, be considered satisfactory, and as a proof of the greater care and consideration given in the present day to the wants and ailings of our poorer neighbours. At any rate, it is something for one capital to have built in less than three years two large asylums for the insane poor, each accommodating 1620 patients, and four hospitals for fever and small pox cases, capable of treating from 5000 to 6000 cases annually, at a cost of nearly half a million of money, all paid for by the ratepayers of the metropolitan district.

If the metropolis has been thus busy for the last few years on works of great public benefit and improvement it cannot be said that the country has been idle. In Glasgow, we have in hand a great university group, not added to bit by bit, but started "*ab initio*" with unity of plan and purpose, and with such architectural pretensions and importance as its educational purposes legitimately call for. In Oxford, there has been of late and still exists much architectural vitality. In the Exeter College

Chapel, the new works at Balliol and at Christ-Church, the restoration of the Cathedral, the new Keble College, and the Churches of St. Philip and St. James, and of St. Barnabas, all bear testimony to the spirit of munificence of their promoters, and if opinion is divided as to the relative or general merit of all these works, I will venture to say without fear of contradiction, that in each will be found points of beauty and originality well calculated to sustain the high reputation of the eminent men who have been working on them.

In Cambridge, the Chapel at St. John's, and the new wing to the library, by Mr. Scott; the new Court at Caius, and the new buildings at Jesus College by Mr. Waterhouse; the important Whewell buildings at Trinity College, with the Museum and Library by Mr. Salvin, and the contemplated enlargement of Pembroke College, all prove that Cambridge is not behind her sister University in such work.

If the great Universities have felt the value and teaching of beautiful and appropriate public structures, the authorities of some of our great public schools have not been backward in the improvement and adornment of their buildings. The governors of Dulwich College have boldly grappled with the heavy task of erecting an entirely new pile of school building; those who administer the affairs of the Charter House have not been less courageous, and a great school establishment of much architectural merit is rapidly making progress at Godalming. At Eton a new Chemical Theatre and Laboratory has been lately erected, shewing what progress is making in the due appreciation of a scientific education.

The great seats of commerce and industry have followed in their appreciation of great public buildings. In Manchester a new Town Hall on a grand scale and of great architectural importance is just begun, and a new Exchange is in progress. In Liverpool a new Town Hall and an Exchange, with a large pile of public offices, have just been completed. In Rochdale and Bradford and Belfast new Town Halls of great importance are in progress, and at Chester a building of similar purpose has lately been completed.

I fear I have already taxed your patience with allusions even to the few buildings I have mentioned, important as they are, but they are but as drops in the great sea of architectural works now in progress in this country. I have said nothing of the numerous Public Halls of Companies or Societies, such as those of the Drapers' Company, the Haberdashers' Company, and the Inner Temple, in London; or of the public buildings undertaken by corporations or counties, such as the Public Baths at Newcastle, the Philosophical Institution and Library at Bristol, the Assize Courts at Durham, the County Lunatic Asylums building in Berkshire, Lancashire, Yorkshire, Cheshire and Herefordshire, or of those for Boroughs at Ipswich, Leicester, and Beverley; and the Guildhall and Municipal Buildings at Plymouth.

I have made no allusion to the numerous private mansions of great importance now in progress in various parts of England, or to the great churches spread and spreading broadcast over the land, though there are many of such great merit and novelty as to demand special attention if time did but permit; or to the chapels, monasteries, convents and synagogues, which are hardly less numerous; or to the schools in towns and rural districts; but I may remind members and those interested in the preservation of our great national treasures, the cathedrals of England and Wales, that at this moment there are very few that have not received, or are not receiving, careful and tender restoration or reparation, for which, within the last few years, several hundred thousand pounds have been liberally subscribed. At this moment no less than fourteen English and three Welsh Cathedrals are entrusted to the care of one (our Leviathan) member, Mr. Scott, in many of which important works are actually in progress, in others merely in contemplation—viz., Westminster and its Chapter-house, Salisbury, Gloucester, Chester, Exeter, Lichfield, Peterboro', Hereford, Ely, Oxford, Bath, Chichester, Ripon, and

Worcester as regards its choir, St. David's, St. Asaph and Bangor in Wales. It would be marvellous indeed, if with such a list of works requiring deep thought and study the world was unanimous in approval of *all* that had been done. There is possibly no race of living men (or women) so difficult to satisfy as Ecclesiologists or Archæologists, or whose views are less controlled by any fixed rules or data; but I beg to bear my testimony to the great care (I might almost say tender faithfulness) with which Mr. Scott has dealt with those restorations which it has been my good fortune to see; and I have heard those who are good judges of the peculiar characteristics of Welsh architecture, speak with great pleasure of the truthful care he has given to the three Welsh churches. I believe that the works at Chester, Bangor, and St. David's are of the most interesting and instructive kind, and that in each of them many features long lost to view have been discovered and laid bare.

These few works must evidently leave Mr. Scott with so much time on his hands, that the Council can have little hesitation in expressing the hope that at no very distant date he may give us a description of some of these recent discoveries and peculiarities.

The work at Bristol Cathedral, under Mr. Street, promises to be as interesting as it is important. It is not an every-day task to build the nave of a cathedral, and we can only hope that in a city and county of such wealth, there may be no lack of funds. Lincoln Cathedral has been intrusted to the care of Mr. Pearson, and, in whatever works may be undertaken there, I venture to believe that even archæologists will be unanimous in their approval.

If the public buildings are thus multiplying in number, and improving in design, it cannot be said that the street and shop architecture of the metropolis is neglected. In the Belgravian district and in other parts private houses have lately risen with considerable architectural pretension and adornment, and I think that the thanks of such a body as our Institute of Architects should be tendered to one who, like the late Lord Westminster, determined to re-build and beautify a large district of the metropolis at the cost of much income to himself.

Gentlemen, this hurried list of works, either actually in progress or but recently finished, is, I think, full of interest for the architect, and of pride for the citizen of a country where such great efforts are attributable almost entirely to the individual zeal, energy and wealth of its inhabitants. I could have extended it largely if time had permitted, and there are several other matters of deep interest for our profession which press on my mind, and which I would gladly have referred to, but in the incomplete condition of some of them, in the delicate nature of others, and in the fact that if health and life are spared me, it will be my duty, in the natural order of things here, to trespass on your patience again next year, it will be better that I bring this crude paper to a close.

It would ill become me, however, as the President of an English body of architects, to refrain from expressing, what I am sure all here and all in our ranks elsewhere must feel deeply, our sympathy and sorrow for the architects of those two great European countries now engaged in such a deadly war, but especially for those of France, trodden down and almost devastated as that country is by the presence of an enemy in her fair fields and in her cities and strongholds. We have no less than forty-four French and German architects members of our body, and three of these have received the honourable distinction of our Queen's gold medal. It is not for me, holding the quasi-official position I have the honour of doing, to attempt to apportion the blame of this bitter struggle (for blame undoubtedly there must be in these "soi-disant" days of civilization and christianity, when two of the foremost nations of Europe are seeking how most readily to destroy the other and undo all the labour of years in art and progress). Individually, I can have no doubt of the deep blame and responsibility. Unluckily, all that we can do is to hope for a speedy termination to such misery, and to be thankful that a similar visitation has not fallen on our own land—a visitation from which France, with all her energy and talent and vitality, will not recover for many toilsome years.

And now, gentlemen, a parting word. One of my predecessors in this chair has said:—"The "architect is he who, with pencil and compass, with a mind full of deep things, under God's providence, "and with his brave heart, creates all this, and toils on unheeded, often misunderstood, frequently "blamed, and rarely encouraged, except by his own bright star of hope and faith. Let us work on "then with the consciousness of something within us which may, sooner or later, before or when in the "grave, be at length understood, admired, and honoured by our fellow men."

I quote these touching words from the address of one whom I am thankful to see still amongst us (a past President and our Honorary Secretary for Foreign Correspondence). I quote them as a true picture of the architect's position, which should appeal to all our feelings. I quote them specially as being descriptive of our friend's own position, for he is understood, admired, and honoured "before the "grave" by all who knew him best; and as being prophetic of the memory in which he will be held by his professional brethren when "in the grave." He will then be "understood" as an ardent untiring lover of his profession and its high calling; "admired" as a genuine warm-hearted friend and cultivated gentleman, and "honoured" for his unsullied unselfish life—an example which we should all do well to follow.

Professor DONALDSON, Past-President (who on rising was loudly cheered), said: I will venture, if you will allow me, Sir, just to say a few words in justification of the Institute as regards the limitation of its members. I recollect the profession before many here—for about half a century: at that time there was a very intimate connection between architects and builders. There were then at the head of the profession two great men, viz., Mr. Smirke and Mr. Soane, whose reputation and honour were unsullied; but in too many cases the architects and builders shared in the profits. Then a very grave movement took place, and it was determined by some young and ardent spirits, that a severance of such connection should take place to remove that scandal. That was the foundation of the Institute,—to establish a body of members purely architects, and not mixed up with builders. It is not that we disregard the builders. They are for the most part honourable, intelligent, and high-minded men; but their duties are distinct from ours, and our professional reputation might suffer by any intimate connection with them; therefore it was determined that this Institute should consist purely of architects, and architects alone. That is the reason why there is such a great difference in point of numbers between this Institute and that of the Civil Engineers, for the engineers have no such restriction. They admit contractors as members, also persons engaged in several trades in connection with engineering. Whereas, if we admitted builders, paper-hangers, plasterers, and decorators—men whom we respect in their several stations, because very much depends upon them in the execution of our works—we should have an Institute as numerous as that of the engineers. It is on account of that abstention on our part that we have kept the numbers down, and that is a stand-point, which I think is to our honour rather than to our discredit. There is another question to which I would call attention; that is, the great number of societies more or less connected with our profession; you alluded, Sir, to subdivision, and you alluded also to unity. I believe, for my own part, that what is called unity in these matters, is not always desirable. I believe that no exertions are so fresh and so energetic as those which are consequent upon a subdivision of labour and competition, as it were, in the race of perfection. Therefore, I think it is, that the various societies of architects have been instituted, and have succeeded to a very great degree. It is creditable to the young men that they should conduct their own societies, that they should frame their own rules and regulate their own proceedings. It is much better than being under the old fogies (laughter), and they would not otherwise have that *élan* and elasticity which they possess in carrying out their studies. I am persuaded, therefore, there would be no advantage in uniting these societies

with this Institute. We have already a large sphere of operations ; and if you knew the labours of the Council, of the committees and of the officers, you would find that the Institute has almost more than it can properly carry out. You, Sir, have mentioned the Slade Professorships. Nothing can be more honourable than the disposition of property from which they resulted ; by the foundation of these Professorships, we may expect a higher appreciation and a greater knowledge, love, and understanding of art in society generally. But there is one circumstance of great interest to us, that is, that two members of our Institute have been appointed to fill these chairs at Cambridge and Oxford. We have with us this evening, a man who was above all fitted for that position, by his great erudition and intelligence, by his large sphere of observation in all countries, by his faculties of speech, and the grace of his pen—I allude to Sir Digby Wyatt. In making these few observations, it would ill-become me after the reference which you, Sir, have been good enough to make to me personally, to do more than simply to propose a vote of thanks to you for the excellent address with which you have favoured us this evening.

Mr. MARRABLE, Fellow.—I have very great pleasure in seconding the vote of thanks. I am sure we shall all hail with gratification any address that comes from Mr. Wyatt, especially when couched in the general and friendly terms by which his remarks to-night have been distinguished. On the individual subjects to which he has specially referred, I am not prepared to say much. The address should, I think, be sent round in a printed form before the opening meeting. At present I cannot carry the points sufficiently in my memory to touch upon them. But I have listened to the address with great gratification, and I hope the promise of future communications from our President will be fulfilled.

Mr. G. GODWIN, F.R.S., Fellow.—As no member rises, I am unwilling that the recognition of the address given to-night should end here. I will take the liberty of saying, as far as I know, we have never had a more comprehensive or more able address. It has taken a very wide view: it shows the remarkable extent to which building operations and designs have been going on in England for some time past: it gives us much to hope for, and much to think of. To that wonderful list of buildings which the President has adduced may be added the extraordinary number of churches, chapels, schools, &c., now being erected throughout the country. Week by week the professional journals bring before us some twenty or thirty of these buildings in operation, and these repeated for the fifty-two weeks of the year, show an aggregate of some 1,500 of these buildings constantly going on in various parts of the country. The greater number of these, I venture to say, display considerable merit ; many great merit ; and but few such features as would be disagreeable or discreditable to the country. I wish to echo the few words with which the President closed his address, in honour of our most admired friend Professor Donaldson, of whom we are all proud, whom we all love. He is one of the few members of the profession who is never afraid of saying the good he thinks, or a kind word to back up a man, especially when he needs it: he never shrinks from any responsibility, and we never hear anything of him but that which is good. Most cordially do I endorse the words which the President has uttered, and I am sure you all join me in that. There are a dozen topics one would like to speak upon. For instance, there is that question of unity with the other societies. I am rather inclined to think with Professor Donaldson, that such a society as the Architectural Association will do better by itself as it is. The programme of that Association for this year is a very remarkable document indeed,—the most remarkable I think they have yet issued. The variety of paths marked out; the enormous means afforded for progress therein, the questions suggested, and the opportunities given, to say nothing of the large number of men who belong to it, point out to me the commendable features of that association It will be the feeder of the Institute. Every man looks forward to his six years of practice previous to his becoming an Associate, and ultimately a Fellow. The most friendly relations should be maintained between the two Associations, as I believe they have ever been ; but I do not see

any great desirability, or any great good that would result from a junction. The Architectural Publication Society may be looked upon as a means of great good, and I am not certain but that if the Architectural Museum formed part of the Institute, it would aid in increasing the importance of the collection, while the Institute in turn would give greater weight to the Museum. The two might, I think, be of mutual service to each other. The step that has been taken in respect of Art Classes seems to me a very important one, and I have no doubt the opportunities they will afford to students will be largely availed of. I would say in conclusion, how much I thank the President for his address, and I beg cordially to support the vote of thanks which Professor Donaldson has proposed.

Mr. BENJAMIN FERREY, Fellow.—I most cordially concur in the admiration which has been expressed of the President's address; but there is one point which I wish he had touched upon. I am aware it is a matter of great delicacy, but it would have been gratifying to the members, if some allusion had been made to it. I refer to the difficult position in which this Institute is placed with the authorities in connection with the Government Office of Works. We have seen in the public papers, and have heard from members of this Institute the difficulties which now exist in reference to our position with the Office of Works. I could have wished we had heard some remarks which might have been of a somewhat soothing character, for, I believe, there is a great feeling of dissatisfaction with respect to the existing relations between the Chief Commissioner and this Institute. It appears that there have been proceedings in reference to a distinguished member of this body which I look upon as a determined attempt to crush this Institute; I say, to crush it, because from what I have read and heard they are such steps as ought not to be taken towards the liberal profession of architecture. Probably, there are good reasons in the mind of our President why that subject has not been introduced into his address; but I hope at a future meeting we may hear something which will make us feel a little more comfortable in reference to the position in which we stand with regard to a great public office.

The vote of thanks having been unanimously accorded —

The PRESIDENT.—I have detained you so long with my remarks that I am anxious to bring this sitting to a close. I thank you very gratefully and cordially for the extremely kind manner in which you have received a very crude paper, one written under difficulties, for I have had to travel a good deal, and I had to write it at short intervals, without much data to refer to; you must therefore excuse its incompleteness and its unconsecutive character. I was anxious to tell you candidly my own views, and to say something that would lead you to deliberate whether my suggestions have any merit in them or not. I was aware that difference of opinion prevails upon some of the points I have referred to, and that I was treading upon delicate ground, but I thought it my duty to tell you candidly my own feelings, and to seek the opinions of others upon them. I was not forgetful of the importance if I could have communicated to the meeting any bright hope on the subject to which Mr. Ferrey has referred. At the present moment the Council have under consideration a very important document which has recently been drawn up by the Office of Works. I hope shortly we shall present a report upon it; and although we may despair of bringing the Government to our views, I think it is very desirable that the public should know the feelings which are entertained by the profession, and the treatment that is sought to be imposed upon it. As to the remarks that have fallen from Mr. Godwin I have said that churches and chapels are sown broadcast over the land, and I had hoped that included a large number. I know they are very numerous. I still feel that a good deal of conscientious difference of opinion may exist on some of the points I have raised. The Council are always anxious to receive suggestions from the members and to give every consideration to them, and to give effect to them if they are calculated to promote the interests of the Association. I again thank you, gentlemen, for the cordial manner in which you have received my address.

The Meeting then adjourned.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, 21st November, 1870, E. I'Anson, Vice-President, in the Chair, the following Paper was read :—

OBSERVATIONS ON THE WEST FRONT OF WELLS CATHEDRAL.

By Benjamin Ferrey, F.S.A., Fellow.

A few observations upon some of the architectural features of the fine west front of this cathedral, which are now brought close to view by the aid of scaffolding, cannot but prove interesting to every lover of ancient art.

A minute examination of the details, whether of the more important sculpture, consisting of figures, viz.:—crowned kings, queens, mitred bishops, princesses, abbesses, nobles, and knights, &c., or of the exquisitely carved, free and beautiful foliage in the capitals, canopies, tympana, pedestals, and terminals, tends to heighten all previous appreciation of these parts of the façade, many of which could only hitherto be imperfectly seen through the aid of the telescope. Freely as all must join in admiration of this wonderful façade as a whole, yet some have criticized portions of the design, and more especially have objected to the composition of the upper part of the front as being unhappy in its outline, exhibiting some unreality in its manner of masking the gable of the nave roof, and as showing marks of an inferior treatment in the lower stages of the front. Undoubtedly there are grounds for these objections.

The crowning range of statues, consisting of the Twelve Apostles, terminates in a noble manner the main elevation of the front. It has been said that the six grand projecting buttresses are unnecessarily large for the constructive uses they were to serve, and are formed rather for the introduction of niches and sculpture than as duly proportioned abutments to the nave arcade, but without a knowledge of the ultimate height to which Bishop Jocelyn proposed to carry the towers and spires (and in all probability he contemplated very lofty structures after the manner of Soissons and Laon Cathedrals), it is unfair to criticize their size. Even, however, with the upper stages of the later terminations added by Bishop Budwith in the fifteenth century, they are scarcely disproportioned; and looking at them as appropriate features for the reception of sculpture, they are most admirably contrived and shew the consummate skill of Bishop Jocelyn.

A distinguished writer and architectural critic, who has lately published three most interesting lectures upon the City of Wells, has, I think, given undue weight to strictures such as the foregoing:

The excessive beauty of the west front as a whole is undeniable, and exhibits genius of the highest order. For its purpose of presenting to the religious spectator in a single façade the portraits of triumphant monarchs, saints and prelates, in one great assembly, the design of the front is unequalled, and small is the deviation from true principles, which has been perpetrated for this great display. How monotonous would have been the west front of this great cathedral if its treatment had followed the hackneyed rule laid down by the author of the "Norman Conquest." Although ordinary artists may fairly be trammelled by such canons as are well set forth by Pugin and others, there have been, and ever will be, men of such originality of thought that their productions cannot be controlled by every day rule. Their works

are stamped with genius, and no better evidence of this assertion can be met with than will be found by those who care to study both the composition and details of Bishop Jocelyn's great work,—the west front of this cathedral.

The general design of the entire façade has been so fully described by Buckler, Britton, Murray, and other writers, and its sculpture elucidated in so remarkably able a manner by our late President, Professor Cockerell, in his interesting work entitled "The Iconography of the West Front of Wells Cathedral," (his interesting theory is well worthy of careful consideration, although probably open to some differences of opinion), that I shall not weary you by the repetition, but in passing I would simply call attention to the remarkably small size of the portals, which are really insignificant in scale as compared with the great continental examples of Rheims, Notre Dame, Paris, and other cathedrals of the same date as Wells. In a design of such splendour the contracted dimensions of these doorways is very remarkable, for though there is a certain boldness of character about the arch mouldings of the coupled doorway, still there is an absence of anything like grandeur, which is so conspicuous in the portals of all continental cathedrals, abounding with statues, enriched moulding and niches, and figures filling up even the arches themselves. It would seem that the designer of this front felt that something was wanting, as there is an evident addition made in a very unusual manner after the central portals were erected.

The arching of the central doorway consists of four borders of deeply wrought mouldings. In the first large cavetto a series of niches and small figures was inserted after the arch was erected; they are not carved out of solid voussoirs, but are skillfully fitted and grooved into the back of the large sunk moulding. The materials of the whole front consist of Doulting stone and blue lias columns, abaci, string courses and pedestals, but this additional enrichment is carved in white lias, and adds much to the effect of the soffit, though palpably an afterthought.

I would also call attention to a peculiarity in the plan of the first tier of niches. In order that this lowest stage might not have an appearance of weakness, and yet that effective shadow might be obtained for the statues, the backs of the niches are set at a slightly recessed angle in the centre, thus giving an appearance of strength to the angular jambs.

In the range of quatrefoils, immediately over these niches, are contained the beautiful Scriptural subjects so ably described by Professor Cockerell, and photographs of which have been published by the Photographic Society, and are exhibited here this evening.

Another noteworthy characteristic is the selection of the subjects of the sculpture as pointed out by Professor Cockerell. They are chosen to impress upon the beholder the grand verities of the Christian faith; and there is a total absence of all apocryphal and superstitious subjects. Whether the intention of the sculpture was to express in stone the glorious theme of the Te Deum as ingeniously suggested by Mr. Cockerell, or with whatever meaning they were executed, they are worthy of admiration, and a higher tribute to the excellence of the figures can hardly be adduced than the praise awarded to them by the great Flaxman, who remarks:

"Bishop Jocelyn rebuilt the Cathedral Church of Wells from the pavement, which having lived to finish and dedicate, he died in the year of our Lord 1242. The west front of this church equally testifies the piety and comprehension of the bishop's mind. The sculpture presents the noblest, most useful and interesting subjects possible to be chosen. On the south side above the west door are alto-relievos of the Creation in its different parts, the Deluge, and important acts of the patriarchs. Companions to these are alto-relievos of the principal circumstances of the life of our Saviour. Above these are two rows of statues larger than nature, in niches, of kings, queens, and nobles, patrons of the church, saints, bishops, andother religious from its first foundation to the reign of Henry III.

Near the pediment is our Saviour come to Judgment, attended by angels and the twelve apostles. The upper arches on each side along the west front, and continued in the north and south ends are occupied by figures rising from their graves, strongly expressing the hope, fear, astonishment, stupefaction, or despair inspired by the presence of the Lord and Judge of the world in that awful moment.

"In speaking of the execution of such a work due regard must be paid to the circumstances under which it was produced in comparison with those of our own times. There were neither prints nor printed books to assist the artist. The sculptor could not be instructed in anatomy, for there were no anatomists. Some knowledge of optics and a glimmering of perspective were reserved for the researches of so sublime a genius as Roger Bacon some years afterwards. A small knowledge of geometry and mechanics was exclusively confined to two or three learned monks in the whole country, and the principles of those sciences as applied to the figure and motion of man and inferior animals were known to none! Therefore, this work is necessarily ill-drawn and deficient in principle, and much of the sculpture is rude and severe, yet in parts there is a beautiful simplicity, an irresistible sentiment, and sometimes a grace exceeding more modern productions.

"It is very remarkable that Wells Cathedral was finished in 1242, two years after the birth of Cimabue, the restorer of painting in Italy; and the work was going on at the same time that Nicolo Pisano, the Italian restorer of sculpture, exercised the art in his own country; it was also finished forty-six years before the Cathedral of Amiens, and thirty-six years before the Cathedral of Orvieto was begun, and it seems to be the first specimen of such magnificent and varied sculpture united in a series of sacred history that is to be found in Western Europe. It is therefore probable that the general ideas of the work might be brought from the east by some of the crusaders.

"But there are two arguments strongly in favour of the execution being English; the family name of the Bishop is English, "Joceline Troteman," and the style, both of sculpture and architecture, is wholly different from the tombs of Edward the Confessor* and Henry the Third,† which were by Italian artists. There are many compositions of the Almighty creating Eve, by Giotto, Florence; Buon Amico, Buffalmacco, Pisa; Ghiberti and Michael Angelo. This is certainly the oldest, and not inferior to any of the others."

For dignity of expression and posture many of the statues can hardly be surpassed, and the affecting series of groups filling the long range of niches over the west triplet window, illustrating the Resurrection at the last great day, are wonderfully fine, and we can only regret that an imperfect knowledge of anatomy has somewhat marred the treatment of this most solemn representation. Nevertheless, the attitudes and expressions of despair and grief are exemplified in a wonderful manner, and the uplifting and rising from the tombs conceived and carried out in the most masterly way. It must be remarked in reference to these several groups, consisting of no less than sixty subjects, that they are not sunk or carved out of the solid masonry, but executed in detached blocks and inserted within the niches. Curiously enough, also, each group has an incised number, still distinctly visible, shewing the order in which they were to be placed to the south of the façade. The bishops have their mitres and priests their tonsures, though, in other respects, all are entirely naked. Above and around these figures must be noticed the bold and splendidly undercut foliage which fills the spandrils, and, although much is decayed, there yet remains a considerable extent of this fine and effective carving standing out in the most artist-like manner; indeed, throughout the whole of this front, the capitals, bases, and hollow mouldings at the back of each of the insulated shafts exhibit beautiful carving, and present an admirable study for the sculptor.

Immediately above this Resurrection stage, as it may be termed, which extends not only across the

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* By Benvenuto. † Wm. Torrell.

west front proper, but fills also the sides of the two towers, there is a central feature, consisting of nine niches, with well-moulded trefoil heads, resting on as many blue lias columns, and containing what has not inaptly been termed by Professor Cockerell, "The nine orders of the Heavenly Hierarchy," though his supposition can scarcely be borne out now that a close inspection of the statues has been made. They may be thus described, beginning from the north: No. 1 is an archangel with double wings, carrying in his hands a regal or small organ. No. 2. An angel, apparently holding a crown in the right and left hands, close to his breast. No. 3. A seraph, entirely feathered, holding a vessel with flames issuing out of it, the legs and feet being also enveloped in flames, probably the Avenging Angel. No. 4. An angel robed in a tunic with an ornamental border, the legs incased in armour, and wearing a jewelled cap. No. 5. An angel beautifully robed, holding a sceptre. No. 6. An angel wearing a helmet, but the figure is too dilapidated to make out what its attributes are. No. 7. A seraph entirely feathered, with bare legs and feet. No. 8. A seraph, apparently holding a banner. No. 9. An angel holding an open book. The niches on the returns of the two great buttresses contain angels blowing trumpets. These nine figures have been supposed to symbolize angels, archangels, powers, thrones, dominions, principalities, authorities, cherubim and seraphim. The sadly dilapidated condition of these statues is truthfully shewn by the series of photographs: they are hopelessly going to ruin, and no effort, I fear, can save them; it is, however, a satisfaction to possess such unquestionable evidence of their condition, and to be able, even in their present imperfect state, to give some idea of their former vigorous outlines. Great difference of opinion prevails as to the course which should be taken with the sculpture, which is so completely crumbling away that no trace of it will shortly remain. Some are for awaiting this result rather than touch the fragile remains, while others recommend that these figures should be at once removed while there is sufficient indication of their character, and be carefully preserved in the cathedral, and that others, executed by skilful hands, should be placed in the niches—a suggestion not unworthy of consideration.

Above the range of statues comes the tier of twelve niches, containing, beyond doubt, the figures of the twelve Apostles—most of them can be identified by the instruments used in their martyrdom, or by significant emblems. And here I may venture to call attention to some matters of detail which Professor Cockerell overlooked. St. Phillip holds five loaves—probably in allusion to the miracle wrought by Our Lord in feeding the multitude—while St. John the Evangelist holds not *a vase*, as was once supposed, but the chalice, from which a serpent is creeping. A peculiarity of much beauty, in the arrangement of these niches and canopies, deserves notice. The present dilapidated condition of the canopies and capitals gives the impression that the greater number of the sustaining columns are wanting, and several are gone, but the fact is, that the series of niches is divided into four large bays, containing in each three figures, the group being separated by projecting columns, while the figures themselves are divided by smaller attached columns at the back of each niche, the canopies to the figures projecting in a pendentive manner, and the soffites formed of free and beautiful foliage. This is an usual treatment, but quite worthy of attention, as shewing the happy manner of relieving the monotony of twelve similar niches as usually arranged.* A very imperfect idea can be formed of the beauty of these canopies, as, with the exception of fragments at each end, the weather has completely destroyed the other parts of the twelve canopies. The figures which fill the niches are, I think, unquestionably, of later date than the rest of the statuary, but they are singularly grand and effective works when

* By a reference to the details of this front, given by Britton in his "Wells Cathedral," it will be seen that his illustrations of this part is most inaccurate, every niche is there shewn as supported by columns on the same plane, and the artist has completely missed the charming deviation from the common rule; probably also, with a view to diminish the weight of the statues pressing upon the heads of the niches immediately under, they are all hollowed at the back to a considerable extent.

considered from the distance at which they were to be viewed. Before describing each, I would call attention to the conventional arrangement of their positions. The Cathedral being erected to the glory of God and in honour of St. Andrew, he, as the Patron Saint, occupies a central position, and is considerably taller than the other Apostles, his head filling the upper portion of the canopy. Another statue, with symbols so completely decayed that his identity is difficult to discover, may not improbably be St. James the Less, the figure being remarkably short and the head unusually large. There are slight traces of colour upon all the figures, and in the protected parts of the robes the deep maroon tint is found. There are no remains whatever of gilding, but the bright colours of the stone, affected by the weather, give almost the brilliancy of gold.

I now come to the upper part of the front which masks the west-end of the nave roof. It is generally admitted that this part of the design of the west front is not successful, it shows evident marks of having been tampered with at some time or other,* and the manner in which the crosses and hip knobs are placed upon the coping of the upper stepped coping of the elevation is not pleasing or effective.

In what way the original finish was intended must be matter of conjecture. The two well proportioned octangular pinnacles, on each buttress, flanking the last tier of niches, undoubtedly belong to the first period, as also the centre part with the large vesica niche, containing the figure of our Blessed Lord,† the two side niches and surrounding embellishments. It is much to be regretted that a part only of this most beautiful statue remains. The upper half of the figure is gone, but the fine drapery with the lower limbs, and the feet pierced by the nails are sufficient to show what a noble statue it must have been. Our Lord is represented sitting upon a throne, the ends of which are shown with the seat rising at a considerable angle, a conventional method much adopted in ancient paintings and religious illustrations. The side niches in all probability contained Angels censing the Divine Personage.

An examination of the masonry of the central pinnacle, occupying the place generally fitted with a floriated cross, shows that the upper part has undergone some alteration. The pinnacle embedded by the coping on each side has its mouldings and bases complete, as low as the string course, immediately over the vesica. On removing the coping it was found to be roughly scribed, and fitted to the octangular pinnacle, and run in with cement, concealing entirely the base of the pinnacle. The perfect shape of the mouldings where so concealed, and the weather worn appearance of the exposed upper portion, shows however that the alteration must have been made a long time since.

The crosses and hip knots upon the ridge of the coping are not set on in sockets like all the other terminals of the front, but are simply fixed with an iron dowel and run in with lead. That this upper part has been altered at some time or other is quite evident, as the present crosses and hip knobs cannot be regarded as the original ornaments. In all probability a large floriated cross occupied the position of the central pinnacle.

Upon the coping immediately over the range of niches containing the Apostles, the bases yet remain of three ornamental objects which once stood upon the ridge. The sockets though not visible from below are yet preserved. In the first edition of 'Dugdale's Monasticon,' issued in the year 1650, there is a view of the west front, showing the terminals, which were then in existence. They consisted of two floriated hip knots between a cross on each side. Their destruction probably occurred soon after that date, as in the second edition of 'Dugdale,' published later, these ornaments are not shown.

It is to be regretted that the original design of the central termination to this front is lost. The

* Most probably in the early part of the 17th century, as among the Chapter Archives, there is a record that owing to the then great expenses in the repairs and works, no stipends could be paid that year.

† There are distinct marks of bullets remaining upon the robe, showing that the statue had been shot at, probably at the time when Monmouth's soldiers destroyed the lower range of figures of the west front.

pinnacle which now occupies the position of the cup, has clearly been taken from some other part of the Cathedral, and been fixed where it now stands. It is of much later date than Jocelyn's time, and may probably have been a pinnacle from a buttress of the Ladye Chapel, for this beautiful structure, beautiful even as it now is, must have been far more so when its external buttresses were surmounted by floriated pinnacles, of which the bases only now remain to prove their former existence. A cross would have been the appropriate terminal, but in all probability this sacred ornament was destroyed when the statue of the Saviour was mutilated, and it is a remarkable circumstance that not a single cross remains upon any of the gables throughout the Cathedral, a fact which would seem to show that puritanical violence was exercised in an unusual degree upon this building.

Although my remarks were intended to apply to the west front proper, it is impossible to limit ones observations to that façade; each return of the west towers exhibits the same vigorous treatment in design which is conspicuous in the great facade, and also shows the utter disregard paid to the works of their predecessors by later architects, who spared neither beauty of form, nor ingenuity in design, if it interfered with new work contemplated by themselves. As a palpable case of this kind I may mention the reckless manner in which Bishop Beckington, in the fifteenth Century, when rebuilding the cloisters, disregarded earlier architecture, carrying his work carelessly against the south side of the south western tower, completely concealing the beautiful arcading which came in his way, not stopping his building to preserve the insulation of the tower, but ramming his late and inferior perpendicular work into the far superior design of Bishop Jocelyn, and both here and in the east wing of the cloisters, barely sparing the most beautiful arched doorways of the south west tower and south transept, the gems of the Cathedral. It was only very recently discovered that a flat wall which formed the north end of a chamber over the cloister, devoted to the Wells Theological College, really concealed the niches and arcades of the south side of the tower, every projecting member having been hacked off, and thrust into the recess so as to make a smooth face; the sharpness and beauty of the fragments can hardly be surpassed, proving that even in pre-reformation times, a due regard was not always paid to art workmanship. The north side of the south west tower happily has escaped any mutilation, excepting such as time and the severity of weather have effected, and notwithstanding the successive changes, when the aisles were transformed from early English, by the addition of pierced decorated parapets above the corbel courses, and the insertion of Perpendicular tracery in the early English windows, there yet remain a few feet of the early drip-stone attached to the tower, showing the height and angle of the original lean-to roof of the south aisle as designed by Bishop Jocelyn, a fragment though small in itself, yet valuable as defining with certainty the original height of the nave aisles. To those who are acquainted with this Cathedral it will hardly be necessary to point out the striking effect produced by the multitude of slender shafts at the several angles of the buttresses, and in the niches and arcades. These shafts, many of them in lengths of 13 feet, in one piece of blue lias, by their number and position form a great feature of the front; unfortunately a number of them, owing to the perishable nature of the blue lias, have either crumbled away or been blown down. At various times, as these accidents occurred, other shafts have been supplied, but instead of being reinstated in blue lias or other grey marble, Doulting stone has unhappily been used. The charm, therefore, which was produced by the beautiful tint of the grey shafts has been wholly lost, and the monotony produced by a large quantity of small stone shafts is most palpable. There are, however, a few of the original shafts yet remaining, and the pleasing effect they produce, especially when the setting sun shines upon them, has only to be seen to be appreciated. Colour entered as much into the minds of the great architects of earlier days as form and composition, and no repairs to this beautiful west front can be effected, which does not reproduce, as far as practicable, the original conception in the colour of the materials.

In an early water-colour drawing of this cathedral, made by Turner, that great artist shewed the beautiful variety of tint produced when a great number of the original shafts were yet standing, nobody knew better how to express in colour the pleasing contrast which was produced by the judicious mixture of these materials.

It is to be regretted that the perishable nature of blue lias renders it unsafe to be used in the proposed restoration, the softness of its colour blending so well with the Doulting stone, points to it as the most fitting material, but after much consultation it has been resolved to use Kilkenny marble instead; its colour resembles blue lias closely, and of its durability no doubt can be entertained, as all the buildings in which it has been employed afford ample evidence of its excellent qualities. The Devonshire and other marbles possess a purple hue very unlike the blue lias, and where so large a number of columns, &c. are required, it is of the highest importance that the colour intended by the original architect should be secured.

Those who have watched the condition of this great western portion of the cathedral have seen with deep regret the rapid decay going on from year to year, every winter or heavy gale produces fresh mischief, and within a late period the fall of canopies and portions of the statues and bases has become dangerous to those daily passing by the north-west corner of the cathedral. So lately as last winter a large canopy fell with a great crash, and it became absolutely necessary that some general examination should be made, to ascertain the safety of many other parts which had a threatening appearance. I was, therefore, instructed by the Dean and Chapter to have a scaffolding erected, and make an examination of the condition of the niches and decorative portions of the two great buttresses of the north west tower: this I did without delay, and I cannot do better than read my report which I addressed to the Dean and Chapter in August, 1868.

"Having by the aid of the scaffolding made a careful examination of the condition of the north-west buttress to the west front, from the top to its base, I am enabled to speak, not only as to the insecure state of many portions of the buttress immediately contiguous to the canopy which has fallen, but also as to the perilous condition of many other details.

"It is of the utmost importance that every feature of this incomparable front should be saved if possible, but this can only be accomplished by a timely renewal of those parts of the design which are essential to the protection of others. By way of example I will only allude to the abaci to the capitals of the upper series of niches, containing successive groups of figures, illustrating the Last Resurrection. All these abaci and their supporting columns were of blue lias, or some imperfectly formed marble; the former have *entirely disappeared*, not an abacus remains; and as a natural consequence, the wet having penetrated to the carved foliage of the capitals, the frost has materially damaged them, and *all* will be destroyed in a short time unless some steps are taken to arrest the progress of destruction.

"Again I find that, although especial care was taken by the original builders to prevent the crushing or injury to the joints by the insertion of oyster shells into all the bedding joints of the masonry, yet sufficient caution was not taken in placing the Doulting stone on its natural bed; hence in many places it has already split and fallen, and there are *many parts* of the west front which must speedily become ruinous, and ought at once to be removed and replaced by good stone rightly bedded. It is not difficult to discover where this defective material is used, as a slight tapping on the face will crush the surface already weakened by cracks and fissures, through which the weather penetrates.

"It is important that nothing should be done to this front but what is really essential to the conservation of the valuable artistic work which remains. Neither *new forms* nor *materials* of any kind should be permitted; it is indeed lamentable to observe the disastrous effects which the last few seasons

have caused to this beautiful façade. A mere comparison of the engraving in Britton's work, published in 1824, with the present state of the front, will shew the ravages which time has produced; but this is not the sole cause of mischief. In former repairs, *cast iron* ties and plugs were extensively used; these have done immense damage, and objects probably safe, if they had been left undisturbed, have been shattered by these injudicious efforts at protection.

"In any other precautionary steps, *copper* dowels and cramps only should be used. I would advise the reproduction of the canopy which has fallen, and also the restoration of the opposite one attached to the corresponding buttress. This has for some time been gradually wearing away. It will be convenient to construct a scaffold from the present wooden framework, and to complete this canopy *before* the other is commenced.

"Although this is the IMMEDIATE work to be done, I cannot but direct attention to the extremely critical condition of many details of this most beautiful portion of the cathedral. In the original design all the angular shafts of the buttresses and wall arcades consisted of a species of blue stone, which formed a most agreeable contrast to the Doulting stone, but unfortunately this has proved a very *perishable material*, in almost every case these columns have failed. At the present moment the south-west and north-eastern buttresses are wholly without these essential features, and although the canopies to the niches retain their position and hang unsupported, yet at any moment they may fall with a tremendous crash, and do great injury. I would therefore very strongly urge the necessity of replacing these missing columns without delay; and would further recommend the use of *some Devonshire marble* instead of Doulting (hitherto employed in repairs), so as to carry out as nearly as possible the original intention.

"The inestimable value of the west front of this cathedral, as being undoubtedly the finest in England, claims for it the utmost possible care; no measures for its preservation should be neglected, nothing but the utmost vigilance can save it from the ravages of time, which are now working slowly but surely its destruction. It is unwise to rest satisfied, and suppose that because up to the present moment certain parts (which looked perilous) have not fallen, they are safe. This is not the case, the very contrary is the fact. Timely measures should be adopted now. I could point out numerous places where, by the judicious insertion of a few new stones, parts now unsupported and dangerous would be rendered quite secure.

"In the foregoing remarks I wish especially to guard myself against any supposed scheme for a general restoration; I simply appeal as a practical man, and ask for the performance of those protective measures which, as guardians of so precious a trust, I am sure the Dean and Chapter will readily grant.

"In conclusion I recommend that each part of the west front should be carefully examined and strengthened where necessary, and wherever it may be found needful to replace carved work, I feel confident that the new portions may be worthily assimilated to the old."

In consequence of my report, the Dean and Chapter feeling that their ordinary fabric fund was insufficient to meet the probable cost of the work of repairs, appealed to the leading people in the county for subscriptions. A committee, with the Lord Lieutenant of the county as chairman, was formed, and in order that no doubt should be entertained as to the necessity of the work, requested the opinion of Mr. Scott on my proposal. Mr. Scott at once made an independent examination of the west front, and confirmed in every respect my report, whereupon the work of repair was without loss of time commenced under my direction. To those who have seen the Cathedral, it will hardly be necessary to point out the important effect produced by the multitude of long slender shafts with which the buttresses are adorned. Amongst the many repairs which have been carried out from time to time, much of the

well intended work was but indifferently executed; thus in substituting light coloured stone for blue lias, as previously remarked, the beauty of the front has been sadly marred. The carving also, where renewed, is both graceless and heavy, and wanting in the freedom and expression of the ancient work, and worse than all, in some cases (though happily few) where the heads of statues were wanting, modern ones of the most miserable description have been supplied; here and there arms have been stuck on in cement; but considering the large number of the statues, we may be thankful that so few have been deformed, and disfigured by clumsy hands. Within my own recollection some of the beautiful heads of the statues have been split asunder, the facial portion falling to the ground in numberless fragments.

Without attempting to draw a close parallel between the west fronts of our several English Cathedrals and Abbey Churches, it may be interesting to compare those which have been most adorned with sculpture: taking therefore those which come under this category, we may mention—Exeter, Salisbury, Lichfield, Crowland Abbey, and Howden—it will be found that the west front of Wells Cathedral supplies by far the most elaborately ornamented example in England. The lower part of the west front of Exeter is a mere appliquè, and consists of two ranges of niches, containing in all fifty statues: many of these are very fine, and the series of cross legged knights on the lowest tier are most interesting; still this screen forms no constructive feature of the west front, and can only be regarded as a display of sculpture independent of any constructional connection with the west front as a whole. The date of this screen is about the time of Edward III.

The west front of Salisbury Cathedral originally displayed a larger number of statues, and was indeed rich in this particular; few, however, of the original figures have been preserved to this time, but those left are sufficient to shew the noble character which must have belonged to the rest. In the late restoration of this front the vacant niches have mostly been filled up with modern statues ably designed by Mr. Redfern. They all represent the personages whose statues were originally there, and whose names are preserved in the archives of the cathedral. By some it has been objected, that the attitudes of a few of the figures are too violent, and that more repose would have been in keeping with ancient examples. Without, however, endorsing this opinion, I cannot withhold my expression of admiration at the artistic skill exhibited by the sculptor, nor refrain from saying that the beauty of the front has been much enhanced by the many figures now standing on former vacant pedestals. It is only to be regretted that sufficient number of donors have not come forward, so as to have all the vacant niches filled.

The west front of Lichfield Cathedral has been so wofully plastered with cement that the bare reference to it causes a pang. As an entire composition it is very beautiful: its exquisite coupled central doorway with exquisite foliated sculpture, its niches and figures, are well known. This front, with its graceful spires flanking the central gable, is most effective in outline: originally it was ornamented with numerous statues, but unhappily few now remain. The elevation may be described as having three leading divisions in height, the lower stage contains a range of small niches and statues, of which the greater part are fortunately preserved, while the next division above, which shows two tiers of pedestals, has not a figure remaining, nor indeed does any figure grace the pedestals of the upper division; it is probable that these figures have perished, not through wanton violence, but in consequence of their exposed position. The two upper divisions of the front are ornamented with recessed wall arcadings, the trefoiled heads of which afford but small shelter for figures standing on projecting pedestals, and the loss of numerous statues may be attributable to this circumstance. The bold overhanging canopies, with deeply recessed niches, at Wells, have served to protect many of the statues which otherwise might have shared the fate of those at Salisbury and Lichfield.

Of the west front of Croyland Abbey Church, which in former days must have been very beautiful (though now a ruin), there can still be fairly traced the original design. On each side of the great west window is a narrow arch in relief, containing four figures, the lowermost standing under canopies. In the upper part of the façade is a range of ten open niches, divided by slender pinnacles, the two extra niches above allow a division of four parts, each of which is occupied by a statue, while the niches above the window admitted one figure each. A list of these figures has been given by Dr. Stukely, who assigned the series to the individual saints and patrons of the monastery, from a drawing in the collection of the late R. Gough, Esq., some particulars of the figures are also given by Carter; there appear to have been twenty-four statues originally. The west fronts of these five buildings seem to have been the only façades which presented in any great degree sculptured representations of sacred and ecclesiastical subjects. The other English cathedrals are almost entirely devoid of niches and statues. Too much store therefore cannot be set upon the considerable remains of ancient sculpture still existing in the west front of Wells.

I stated that it was not my intention to give any minute description of the various statues; they have been ably characterized by the writers I have mentioned. My purpose has rather been to show that some steps are being taken to arrest the further progress of mischief, and if possible to secure the preservation of by far the most valuable collection of statues yet remaining to us from the middle ages in this country. The erection of the very complete range of scaffolding has given an opportunity of developing some details of which we had previously little knowledge, and as I believe there are some learned antiquaries who have expresssd doubts, and still entertain them, as to the identity of many of the personages represented in sculptured stone, let me recommend that they avail themselves of the commodious and safe platforms, to make such a minute examination of the figures as may set all doubts at rest.

The reading of the paper was followed by the exhibition, by means of the oxy-hydrogen light, of a series of photographs, by Mr. Flukes, of Bath, illustrating the descriptions of the sculpture, &c. given in the paper; and in reply to various inquiries, Mr. Ferrey stated that a complete scaffolding erected at considerable cost, embraced the whole of the west front, from which the examination as to the condition of the statues, &c. had been made. The first series of illustrations consisted of subjects from the Old Testament history, commencing with the creation of man. On the south side of the front are the effigies of bishops and other religious persons; on the north side those of kings and various secular personages. Above these are groups of figures representing the resurrection. The smaller niches are occupied by figures of the nine orders of angels. With regard to the western towers of the Cathedral, Mr. Ferrey stated that the question of their completion had not at present been entertained. With reference to one of the figures exhibited, he stated that a portion of it fell a few years ago, just at the moment that the Judges of Assize were entering the Cathedral. It had been replaced, but it would be seen how inferior the head was to some of the older work. Mr. Ferrey further remarked that the moment the colour faded from the blue lias the safety of the figure ceased. Upon the exhibition of the figure of Edward the Elder, Mr. Flukes stated that the figures, as shown by the lens, were about the original size of those in the building, which varied from 7 feet 10 inches to 8 feet 1 inch. These were the general heights; a few of them, he said, were 8 feet 10 inches. On the exhibition of the figures of the Apostles, it was remarked that these were all the original work, though in some places it was patched with cement; and in reference to the figure of St. John, which was represented as holding a chalice, from which a serpent was issuing, Mr. Charles Barry explained that the legend was, that

poisoned wine was given to the saint, but on his blessing it, the poison, in the shape of the evil spirit, departed from the cup. The illustrations concluded with views of the exterior of the Cathedral and the Bishop's palace and gardens.

The CHAIRMAN having invited remarks upon the paper—

Professor ANSTED said, I ought, perhaps, hardly to commence the discussion upon a paper of such extreme interest in an architectural point of view, by referring to the stone used in the portion of the structure which has been so well described and illustrated. But perhaps after all the question of material is that which should come first under the consideration of the architect in any great work, whatever it may be. With regard to Wells Cathedral, I know it tolerably well from a careful examination of it about ten years ago. I am also acquainted with its history, and from my own observations, as well as from the accounts given by those who have described the material at different times, it is clear to me that the stone, which is now undoubtedly in a bad state in the west front, was in a very much better condition thirty or forty years ago, when Britton described it, and even when it was examined by the Commissioners appointed to inquire into the nature of the stone to be employed in the Houses of Parliament. At that time the material was described as being in a fair state of preservation; and the Doulting stone used in the west front was referred to as a material of great durability. Perhaps the most interesting portions of the illustrations exhibited this evening are those which show very clearly indeed the state of decay of the stone in many places at present; but still, as a whole, there is no blame in the selection. The Doulting stone is one of the oolites common to that part of the country, and on the whole, except in particular instances, the material has been well put into place, and has answered its purpose well. We must not expect that a building, however carefully constructed of any of the ordinary stones of this country, will last more than a few centuries without continual attention. It is necessary from time to time that a building should be examined, and faulty stones replaced by others; and it appears to me that the chief thing to regret, and even perhaps to blame, is that thirty or forty years ago, at a time when there is reason to believe that most of the sculpture was in a better state, it was not attempted to reproduce the works of art in a permanent form, retaining the decaying statues in some convenient place. I think it will be recognised as a valuable lesson in reference to material, that this stone really stood well for 400 years, and yet, within the last fifty years, it has decayed to such an extent as to make it necessary to replace very important parts. It shows that this particular stone, and I am sure we may assume the same of other stones, requires looking after. It is a matter of great interest to be able to study the exact condition in which these stones now remain, if we cannot do it by visiting the structure, at least by means of illustrations such as we have had this evening. I noticed particularly in these illustrations the condition of the columns, constructed, as it appears, of the lias of the Street quarries, as compared with that of the limestone used for the statues and niches, and it seems to me that the lias has stood as well in proportion as the harder and no doubt better stone. The actual specimens of the lias made use of must have been selected with extreme care, and I think they may have been exposed to some treatment of drying or preparing before being put into their places; for I can hardly conceive that the atmospheric changes which take place in an exposed building, at a great height from the ground, would spare such a stone in an unprepared state. If so exposed now, the stone would hardly last more than about fifty years. I think at least that experience would show that delicate work in lias would not now stand much longer than that without change; and I can hardly conceive this material would last 400 years with so little alteration in some parts of the west front of Wells Cathedral without having been subjected to some treatment by which its resistance of atmospheric influences was increased. Perhaps an examination of the surface would

tell that. At any rate, the subject is one which deserves attention, and the more so since it is evident that parts of the stone were coloured most likely with a view of checking the action of the weather. With regard to the material with which it is proposed to replace these faulty portions, Mr. Ferrey states it is the intention to use Kilkenny marble in place of the lias. It is possible that may be a good material, and answer the purpose well. It is also possible that the Kilkenny marble may not last longer than the lias has done. The earthy marbles of this country are not generally very desirable for outside work, though in some cases they stand well. They take a good face and polish, but the polish almost immediately disappears, and when the frost gets in, they are apt to fall to powder sooner than some of the less compact and less crystalline stone; for after all these marbles are only partially crystallised, and are liable to a considerable amount of variety of condition.

The CHAIRMAN.—Is it an oolite of the Portland kind?

Professor ANSTED.—It contains very few oolitic grains. It is a well-defined stone with a good face —not exactly crystallised, closely compacted, but with very few oolitic grains.

Professor DONALDSON.—I think the Kilkenny marble alluded to is not a marble. It is a very hard stone, almost indestructible by time, and very difficult to work. I think we must not put it in the category of marbles. I believe it darkens very much in colour by time.

Mr. G. W. HEMANS.—I have had the opportunity of constructing a railway from Kilkenny to the north of Ireland, and in building the bridges the stone of the country was used, and I can say it is a marble of a hard and compact character, and capable of high polish. It is a durable and handsome stone, and I should think suitable for the ornamental portions of a cathedral.

Mr. J. P. SEDDON.—There is a stone which I have used for these purposes, called the *Hanam* stone, near Bristol. It is a close, hard sandstone, which I believe is very durable, and is a beautiful pale blue colour. I don't know whether Professor Ansted can tell us what the stone is which is so generally used throughout Germany for these purposes?

Professor ANSTED.—That is muschelkalk, a limestone belonging to the new red sandstone series. It is, as Mr. Seddon says, used throughout Germany; but there are also other limestones, some of the age of our oolites, but not generally oolitic. They are compact and durable.

Mr. CHARLES BARRY, Fellow.—Leaving now the geological part of the question, which, though interesting, is not perhaps the main point of interest before us as architects, I would only remark in passing, that I fancy the difference Professor Ansted intended to make between marble and compact limestones was, that both being limestones, marble is highly crystallized, but that there are a great many limestones not crystallized, but compact enough to take a high polish. The purpose, however, for which I rise, is to propose a vote of thanks to Mr. Ferrey for the extremely interesting paper he has given us, artistically speaking. Of course most gentlemen present are, more or less, acquainted with the artistic peculiarities of the general design of the west front of Wells Cathedral, and for that reason Mr. Ferrey has not dwelt much upon them, but has chiefly confined himself to the condition of the sculpture forming part of that design, and of which he has made a personal examination in great detail, and has laid before us information of the highest possible interest. On the theory as to the meaning and signification of these figures, propounded by the late Professor Cockerell and by Mr. Planché, I do not think it is important now for us to enter, because I think the application of sculpture all over the front of a building, as in Wells Cathedral, is mainly, if not solely, for the sake of architectural enrichment, and should primarily be looked at in that sense. Many little peculiarities and conventional treatments of length, breadth and anatomy, may thus be admissible, and are not to be criticised in these particulars, so long as they satisfactorily produce that architectural effect which I have ventured to describe as enrichments of a peculiar character and the highest order. The application of sculpture

in this particular case we shall all probably, from our observation of Wells Cathedral, consider very happy. The mode in which the sculptures are introduced, enriching the surface without destroying the main lines of architecture, is very beautiful, and is worthy of the study it has always received. Another remark occurs to me, and that is, that these photographs of the figures, so quaint and perfect in themselves, are of the greatest possible interest to architects and architectural carvers, for this reason, that they show them as they are on a level with the eye, and so that we can examine them as carefully as if on the scaffold which has been erected. They show the manipulations which the carver actually gave in order to produce the rich and beautiful effects which we notice on viewing them from the ground level, from which, of course, they were intended to be viewed in the case of this cathedral. Stone carvers, without the opportunity of studying them so closely as these illustrations enable them to do, might go away with the idea that they could produce the same effects, but, lacking the actual method, might be deceived. For this reason, among others, it seems to me that this series of illustrations is peculiarly interesting. There are other considerations suggested by them, into which at this late hour I will not enter, and therefore will not detain the meeting longer, and not doubting that I shall find an enthusiastic seconder, I beg to move a cordial vote of thanks to Mr. Ferrey for his paper.

Mr. C. F. Hayward, Fellow.—I shall be too happy to second the motion. To anybody who has spent any considerable time in the examination of this cathedral, the paper we have heard must have afforded extreme enjoyment. To myself it has been a great pleasure to see, so much better than I did during my two or three days' stay in Wells, the figures and carvings, which I was unable, after hours of looking at them, thoroughly to make out. But there are many other figures besides those on the west front. All the interstices of the buttresses at the back, towards the east, are filled with figures, and I have spent a summer's day sitting in the gutters sketching some of them, not having the accommodation of a scaffolding for the purpose. As we all know, Mr. Ferrey, junior, has made a very fine study for the restoration of the Metropolitan Cathedral of St. Paul's, which gives us some idea of what it was in its grandeur, and I would suggest that the same gentleman could find no finer object for a similar study than is afforded by this cathedral of Wells; it could be placed in no better hands. It is, perhaps, not easy to say what was originally intended with regard to the termination of the west front, but I have often felt the desirability of ascertaining, if possible, and with the opportunities now afforded it would be an excessively interesting study. I hope Mr. Ferrey will take it up, and give us the benefit of his researches. Perhaps some of us may even live to see the completion of the towers themselves.

The vote of thanks having been unanimously agreed to—

Mr. Ferrey said, Before expressing my thanks for your kind approval of the few remarks I have made, I would say how much I am indebted to Mr. Flukes for the successful way in which he has aided me by his illustrations. I regret that some of the able professors of sculpture, who I expected to see here, are not present. I had hoped that Mr. Westmacott, Mr. Woolner, and other sculptors, would have found leisure to give us the benefit of their remarks upon these works of art. I am very thankful for such observations as have been made, and I shall take care to bear them in mind in carrying out the work entrusted to me. With regard to the nature of the material to be used, I agree with Professor Ansted, it is a subject of the highest importance; also that the blue lias used in this structure has stood remarkably well, but it has been chiefly in sheltered nooks and corners. In every instance where the blue lias stood in an exposed position, it has failed. I may say that I stood out as long as I could in favour of the blue lias, but I was so overwhelmed by evidence of its uncertain character, that it would be an unwise thing in the new work to use a material which had failed so extensively; I could, there-

forc, no longer press my own view of the subject. One cause of the failurc of thc shafts was, I think, that they were vcry long, and have no joints, and are sct into sort of cups at the base, and the wet getting into the cups caused disintegration to the bascs. I urged that thcre was no proof that blue lias would ordinarily fail from disintegration. In situations where the lias was not so exposed it stands to this hour; but there was no withstanding the evidence before one's eyes, of the most complete dcstruction of the beautiful shafts which stood at the corner of each buttress. Devonshire marblc has been spoken of, but its colour would not harmonize with the other portions of the work, and to introduce a large quantity of marble, differing in colour from the material formerly used, would, I think, bc a great mistake; therefore it was we had recourse to the Kilkenny stone or marble, bccause we had most distinct evidence that it had stood for centuries as beautiful and as sharp as ever.

The mceting then adjourned.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 5th December, 1870, T. H. WYATT, President, in the Chair, the following Paper was read:—

A BRIEF NOTICE OF THE LATE SIGNOR RAFFAELLI POLITI, OF GIRGENTI, SICILY, HONORARY AND CORRESPONDING MEMBER.

By Professor DONALDSON, P.P., Hon. Sec. For. Corr.

IN attempting a short Memoir of our deceased colleague, I am reminded that so long ago as 1812 our late President, C. R. Cockerell, Esq., made his acquaintance at Girgenti, as I also did in the year 1821. He was then in all the flush of youth, of an eager earnest temperament, and following up the studies of archæology and the fine arts. The love of them was inpressed throughout his whole nature, and was the passion of his existence up to the last moments of his life. We, who live in the centre of a vast capital, and have the freest access and command of every facility for study and the practice of our art, can scarcely form a conception of the struggles to be gone through by a young man in a remote country, without books, without a congenial and inspiriting circle of educated friends, and without the commonest materials at hand to enable him to realise the fruits of his own conception, and upheld only by the strength of his convictions and inspirations.

Girgenti, although lying in the southern coast of Sicily and with a harbor, small and insufficient it is true, is almost entirely without commerce, and nearly without relations with the outer world. The town, although surrounded, as it were, within its circuit by a halo of many well-preserved temples of the noblest class, and by numberless and as yet unopened tombs of the classic period, enclosing artistic riches of vases, bronzes, and like deposits, and with a good-sized cathedral far famed for its echo, boasts only of one street. To give you some idea of the modest pretensions of the town, I recollect a witty French writer of that period commencing a letter thus: "From the only guest chamber, of the only inn, in the only street of Girgenti, I write these lines." In fact, travellers were scarce, for hardly a carriageable road existed through the island, and the way-farer had often to be indebted for bed and board, in the absence of inns, to the welcome and frugal hospitality of the monasteries and their open-hearted inmates.*

It was in such a place, and under such circumstances, that Politi painted, having to prepare his own canvas and grind his own colours. He excavated among the Greek sepulchres, enraptured by the beauteous forms of the ceramic vases covered with exquisite historical paintings. He pored over the few books he had purchased with his humble savings to find out the subjects; he delineated them, and wrote descriptions of his findings. Himself composed the type, and printed many of them in a press he had set up in his own house. He also engraved the plates, and struck off impressions in the like

* A passage in Mr. G. L. Taylor's Autobiography, hereafter noticed, confirms my experience upon this point (page 144).—"We could not obtain a room at the Inn (Castel Vetrano), and therefore followed the recommendation of the people to go the Convent of the Domenicans, where we waited till our patience was exhaused for the arrival of the Superior, and then sallied out into the town to endeavour to find other quarters. We did so at the Cistercian Convent, and returning to fetch our goods there were most kindly and hospitably received by the whole of the brethren, who vied with each other disinterestedly to assist us."

manner. He did not get rich by such works, there being little or no sale for them at Girgenti, and he distributed them freely among his friends. There is an incident connected with one of his pamphlets of peculiar interest to us. From his study of the vases, and a comparison of the subjects with the outlines of our own Flaxman, a copy of which he possessed and cherished as a treasure, he entertained the deepest reverence for the talents of our countryman. A false report was current in 1826 throughout Europe, as even previous ones had been, that Flaxman was dead; but he had been only seriously ill and was recovered. Politi, with his usual characteristic impulse, was struck with sorrow for the supposed death of a man, whom he considered to be one of the most illustrious of artists. He had recently extracted from a tomb an unique Greek vase* with a beautiful subject, and had completed a description, which he had illustrated by a plate. He dedicated it as a fitting tribute to the *shade* of Flaxman, and sent over to me twenty copies to distribute among our sculptor's friends and admirers. But here was Flaxman living! and I felt embarrassed. However, I soon made up my mind, knowing Flaxman personally, and assured of the calm religious philosophy of his nature, I called upon him and frankly told him my commission. He answered me with his usual placidity, "I value your frankness, and appreciate fully this warm-hearted act of the Signor Politi. Be not disquieted, it does not otherwise affect me, for a man at my age ought always to be prepared to die." Within a month Flaxman was laid in his grave!

In Girgenti, as travelled architects are aware, are the ruins of the immense temple of Jupiter Olympius, rivalling for extent even those of Selinus. Its plan occupies a parallellogram, about 363 feet long by 177 feet wide. It was pseudo peripteral, having an enclosure wall all round, with fourteen attached columns on the flanks, and space for seven at each end,—the angle ones included in all forty-three. The columns were 13 ft. 2 in. in diameter, and I could easily lie in one of the flutes. To the classic student this was a riddle, for apparently in the middle of each end front there would be a central column like the Basilica at Pæstum. But there was still another riddle to solve. Among the ruins, when the government had had the site cleared so as to expose all the blocks of stone, were parts of colossal statues, and the several portions of a complete figure 25 ft. in height were collected and put together, lying at full length on the ground. It was evident that the figures had not been isolated but attached. Tradition had for ages given the name of the Temple of the Giants to the mass, interspersed as it was with fragments of those figures; and the modern city in the middle ages had adopted three of them for their arms,† and I exhibit a drawing made when I was there. In the centre is a female, and on either side a male, in one row, with upraised arms supporting a band with the words—

SIGET. AGRIGENTVM. MIRABILIS. AVLA. GIGANTVM.

Up above rise three embattled polygonal towers, the middle one surmounted by the letters YHS, encircled in a glory.

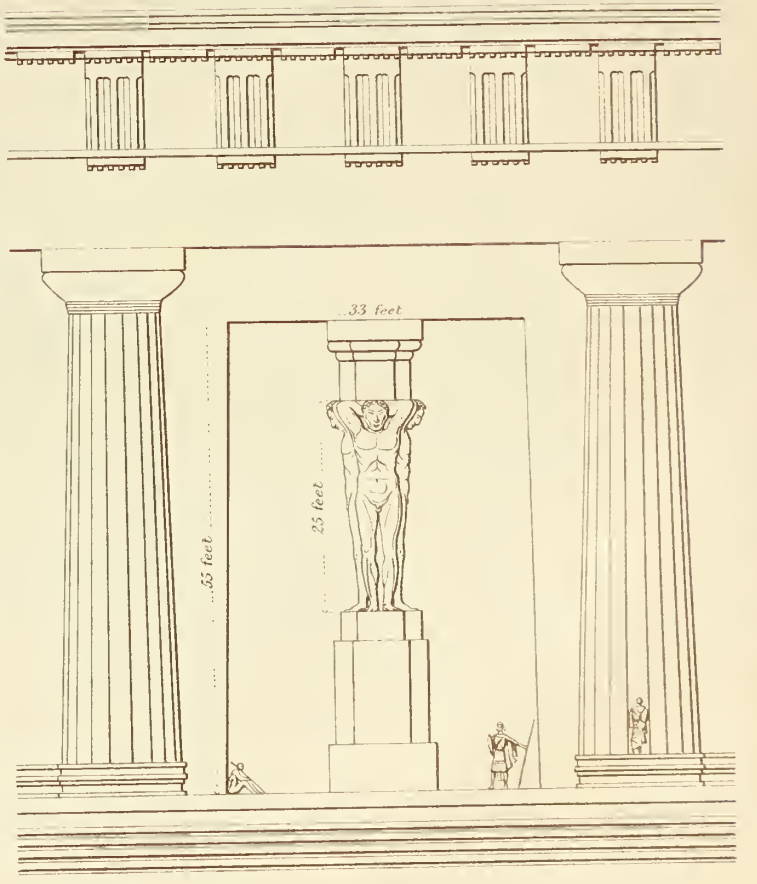
Politi took upon him to solve this riddle, dissatisfied with a design previously made in 1812 by his friend Cockerell, who had left with the English Vice-Consul a sketch, shewing a row of Titans between the windows of the clerestory wall of the restored nave, and upholding the roof. This is published in the supplementary volume of Stuart's Athens. But this arrrangement required twenty-four giants, and there were discovered only the parts of four, according to my own observation, one a female; Politi could then only see three. Our friend pondered over the puzzle of the proper allocation of these few colossal statues, and a passage in an old writer, Fazzello, who states "that there was a mass attached to three giants, and certain columns still remaining upright. These stood till 1401, when, from neglect of the Agrigentines they fell down, forming a vast pile of stones vulgarly called the Palace of the Giants."

He published a folio work, a copy of which I now present, with four plates giving the plan; restored elevation and details of the parts still existing; and to obviate the irregularity of a column in

GITY ARMS OF GIRGENTI.

THE TEMPLE OF
JVPITER OLYMPIVS, AGRIGENTVM.

THE DOORWAY AS PROPOSED TO BE RESTORED BY SIGNOR RAFFAELLE POLITI.



Columns 13ft 2 in. diam.r

THOS L. DONALDSON, DEL.

Kell Bros lith London

the centre of the front he introduces a vast aperture, 53 feet high and 33 feet wide, divided in the centre, as in some of the Gothic cathedrals, by a clustered shaft, the upper part of which consists of three gigantic figures. Such an arrangement under the circumstances is a clever adaptation, but the classic scholar of our art will consider it rather as fanciful and ingenious than as legitimate or thoroughly satisfactory. Whereas Cockerell's position of the giants is perfectly in accordance with precedent, and Politi, in 1825, had discovered the fragments of ten figures! In fact the two friends seem to have reveled in the opportunity of producing something novel and effective to meet the difficulties as to the position of the giants; and probably no more rational scheme will ever be suggested to settle satisfactorily the problem of the restoration of this original and truly gigantic production of Greek art.

Mons. J. J. Hittorff in the noble posthumous work, recently published by his son, omits the central column of the front, and introduces a doorway with an opening almost as large as that of Politi's, with the usual dressings; but unless these were made to advance before the face of the wall, as much as the columns project, there would not be any sufficient support for the architrave in this wide intercolumniation of nearly 40 feet. From a very minute study of the indications of the construction at the level of the floor line, my own impression confirms that of Mr. Cockerell, that there was a (comparatively) small door at each end of the front next the angle columns, and thus entering direct into the side aisles and not into the central nave.

Politi was a man of immense energy. He built a theatre and wrote pieces; for his comic vein, the peculiar natural gift of the Italians, was overflowing: and even in his letters there was a bright spirit and sparkling wit, which seemed to counterpoise the depression in which he too often wrote to me. The government appointed him Curator of Antiquities, which yielded him local importance rather than official honoraria. He was also Consul for some foreign state, which entitled him to certain immunities. Thus he struggled on with adversity up to his death; painting and writing being his great solace: "*labor mihi sola quies*," his oft-repeated motto. He was honored by those few congenial souls who knew his qualities; and by the rare intelligent travellers, such as our own Samuel Angell, when engaged in laying bare the archaic remains of Selinus; by G. L. Taylor, our Fellow, as mentioned in his Autobiography just published; and by our valued Honorary and Corresponding Member, the late Monsieur Hittorff, who got him named Correspondent of the Institute of France. He valued such connexion with the various learned and artistic societies of Europe, whose members willingly associated his bright genius with their own researches. But the cares and expenses of a numerous family, the loss of his beloved wife, increasing infirmities, and advanced years weighed heavily on his elastic spirit, producing great nervous irritability, and he closed his career of intelligence and usefulness in October last, fully eighty-six years old, and I fear in want, sorrow, and bodily suffering.

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* Another vase, which he described and of which he gave a plate, had on it a very amusing subject, precisely the same as the plaister copy of one of the metopes from Selinus, discovered by Angell and Harris, and now in the British Museum, representing Hercules Melampyges carrying on his shoulder his bow or branch of a tree, with a man bound hands and feet hanging from either end. These were two robbers, Passalus and Achemon. They were about to start upon one of their predatory excursions, when their mother warned them, if they met with a stout fellow with thick black hair on his loins, "a tergo," to avoid him, or they would get the worst of it. They by chance came where Hercules was lying asleep on his back, and they began to plunder him of his cloak and rest of his clothing; but he soon got up, seized them both, bound them hand and foot, and swinging them on the ends of a pole or his bow on his shoulder walked off. After proceeding a short way the one behind exclaimed, "oh!

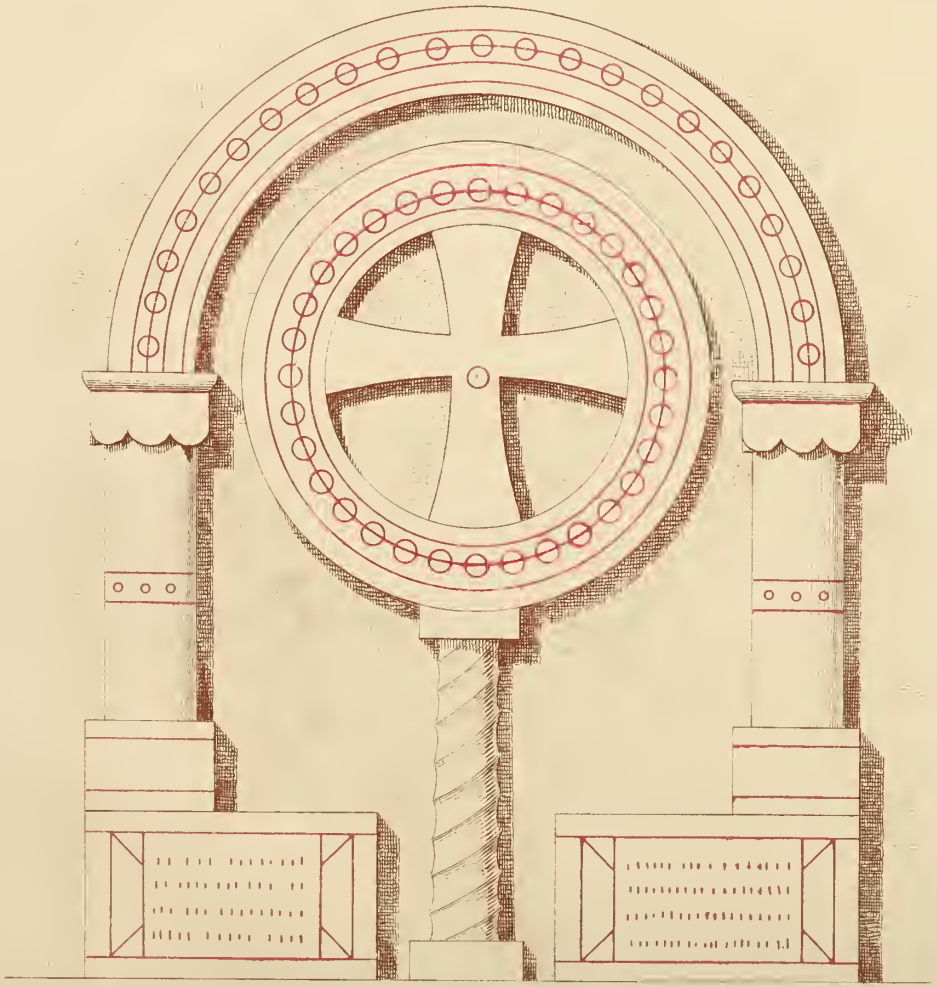
brother, brother, what fools we have been, here is the man with the black-haired loins, of whom our mother warned us." Hercules asked them what the exclamation meant, and it being explained, he fell a laughing, loosed their bands, and set them free.

† This coat of arms of Girgenti is a very curious memorial of the XVIth century, embodying both classical and Mediæval allusions. Above the central turret is the sacred monogram YHS, the stem of the H being lengthened into the form of a cross, the whole encircled by a nimbus. On the right hand side tower are the abbreviated words "Sancta Maria Domini Genitrix." The vertical line of letters, next the figure to the left, indicates "Nomina Gigantum Enceladus," a son of Tartarus and Ge, who, when he was slain and cast on the ground, had the island of Sicily thrown upon him to keep down his rebellious spirit, as mentioned in the Æneid, book 3. "Fama" is described in book 4 of the Æneid. The expression of her mouth, even in the rough stone, is wonderfully fine. "Cæus" is less known than his brother; but is named by Virgil, Georg. II, line 278. It thus appears that the artist, although alluding to a Greek town and Greek monument, borrows his illustrations of the figures from the Latin Poet.

IN ILLUSTRATION OF THE

ARCH OVER THE TOMB OF CHARLEMAGNE.

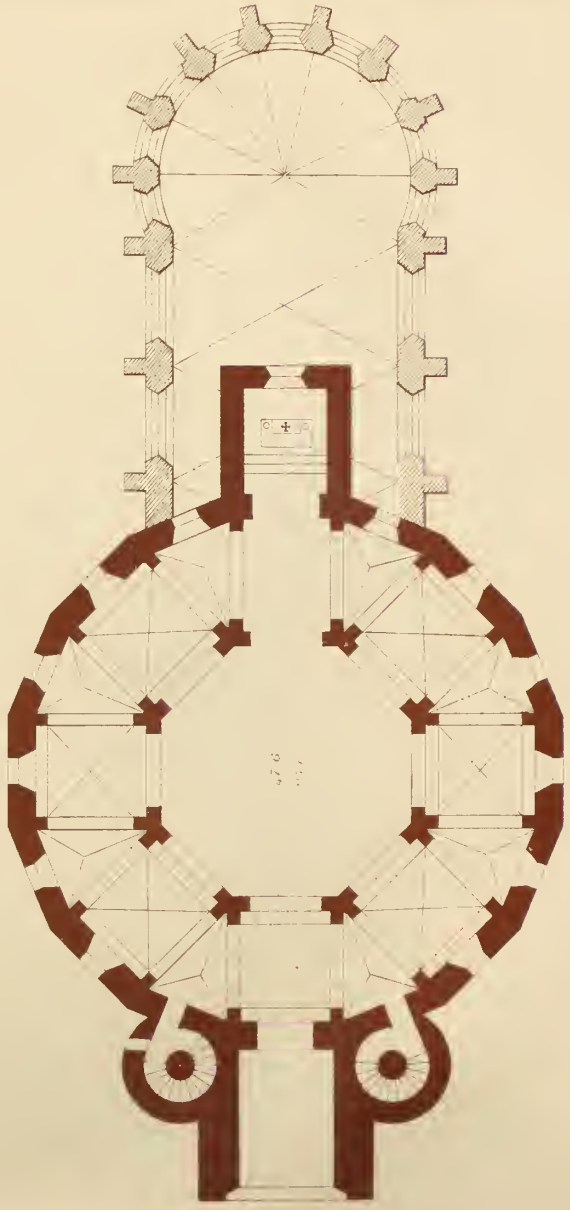
HALF SIZE OF THE ORIGINAL.



CEMET CYRIACAE.

S. GIOVANNI. ROMA

THOS L DONALDSON. DEL.
MARCH, 1869.



CATHEDRAL OF AIX-LA-CHAPELLE.

Zeil Bros Lith London

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 19th day of December, 1870, E. l'Anson, V. P., in the Chair, the following Paper was read:—

ON THE MYSTERY OF THE TOMB OF CHARLEMAGNE, AND THE RESEARCHES MADE OF LATE YEARS TO DISCOVER ITS ACTUAL SITE IN THE CATHEDRAL OF AIX LA CHAPELLE.

By Professor T. L. Donaldson, P.P., Hon. Sec. For. Corr.

It may be remembered by some present, that, in the year 1852, I ventured to call the attention of the members to the lamentable condition of the Royal Tombs in Westminster Abbey. Perhaps there is no more striking illustration of the ephemeral nature of such memorials, and of the little respect paid to (what one might call) such sacred depositories of the great and the good of past times, than the present condition of these most magnificent sepulchral erections throughout the world. Let us regard the Pyramids of Egypt, now visited merely as stupendous shows, gigantic productions of four or five thousand years ago. The tomb of Mausolus, one of the seven wonders of the world, whose fragments have been transported to our Museum, to teach the rising artists of our own times. The Mausoleum of Augustus, the first great Emperor of the line of the Cæsars, now a huge mass of brickwork, despoiled of all its statues and marble facings, I have seen used as an arena for bull fights: and the gorgeous Mass of Hadrian, at Rome, whose zone of Corinthian columns of Greek marble was the proudest feature of St. Paul's without the walls, 'ere it was burnt down, is now serving as a fortress to overawe the City or be a refuge of menaced Popes. We see the tumuli of our own forefathers mercilessly cut into and ransacked for the sake of a piece of pottery, a flint spear head or a bronze blade. Such is the story taught us, as to the fate of these pious memorials of the grief or respect of the survivors for the dead; men noted in their time, whether as potentates or warriors, the learned, the illustrious or the pious of periods long ago. In illustration of this, I beg to trespass upon your time to describe the strange fortunes, which have attended the depository, in which lay the body of, surely I may say, the greatest warrior of the middle ages, the Emperor of Germany and France, Charlemagne. I think I hear many of you exclaim, "Oh, we know where it is, in the Dom of Aix la Chapelle, under the large slab with the inscription KAROLVS. MAGNVS." You will, possibly, be surprised to hear, that not a trace of the sepulchral vault is to be found throughout the area of the cathedral: and that the slab with its inscription is an apocryphal act of the French Bishop of Aix at the beginning of the present century, and most probably *not* over the spot where he was buried in his royal crypt, where, as the Poet* says,—

"In Aachen Abbey's consecrated ground,
Within the hallowed stone,
They placed the Imperial body, robed and crowned,
Seated as on a throne."

Before we proceed to consider the posthumous facts connected with the Emperor, permit me to

* Monckton Milne, now Lord Houghton, "Lay of Charlemagne, and the Hymn of Christ."

recall his personal appearance, the extent of his rule, and the circumstances connected with his death and burial.

Charlemagne, the son of Pepin, founder of the Carlovingian dynasty, was born 2 April, 742. Robust in person, he had large and piercing eyes, a long nose, with a frank agreeable expression. When he stood erect, he was taller then those around him, being seven feet two inches high and had great dignity of presence. He was of such prodigious strength, that with his famous sword Joyeuse he could with one stroke cleave a knight on horseback from his head downwards. On all public occasions he wore magnificent robes, splendid with gold and precious jewels; but, on ordinary occasions, his dress was very simple, and his repasts were very frugal but very ample. He was very eloquent, and had a great love for letters and the arts, and he built considerably,* a taste which he acquired during his visits to Italy, then distinguished above all countries by the great productions of its artists and the noble remains of classic antiquity. Although despoiled of much of their ancient splendour, these still retained, by the grandeur of their proportions and nobility of design, an imposing aspect, the surviving prestige of the early times of Rome; and this enabled them to rise superior, even in their state of ruin. Attired in his splendid robes, seated on his marble throne, and surrounded by his nobles and officers of state, he received Ambassadors and Envoys from the Court at Constantinople, from Haraoun-al-Raschid at Bagdad, the Emirs of Spain, the Kan of the Huns, the Sovereigns of Fez, and the dethroned Kings of Sussex and Northumberland, Egbert and Earduff, who all brought him the choicest productions of their countries. His own empire extended from the mouths of the Elbe to the Gulf of Gascony, and included all Germany, France, and the western side of the Pyrenees, Italy, Dalmatia, and Countries of the Sclaves, Bohemians, Croats, not to mention many islands on the coasts, and others, comprising many families of peoples and as various tongues. He died on the 28 January, 814, after an anxious and ever active reign of forty-seven years. Aquisgrana, now Aix la Chapelle, was his favorite place of residence during the latter years of his reign, attracted by its chemical waters, in which he frequently bathed. In this imperial city, towards the close of life, Charles erected the Mortuary Chapel or Cathedral, in which his remains were to be interred: and to give it the utmost sanctity he built it in a circular (or rather polygonal) form of plan, to coincide somewhat with the traditional holy sepulchre at Jerusalem.† It was solemnly consecrated in the year 804, by Pope Leo III, with a ceremony worthy of its destination and splendour. Three hundred and sixty-five Archbishops and Bishops were present at the ceremony, with a pomp like that of an Œcumenical Council.

The full understanding of the plan of this building is so necessary to the comprehension of the circumstances, to which I am about to allude, that I shall at once proceed to describe it and the arrangement of the several parts.

The church had a large open projecting porch, forming the entrance, flanked by two circular towers, in which are ample staircases. The centre consists internally of an octagon with an arched aisle all round, and on the further side, opposite the entrance, was a square sacellum or sanctuary, or altar recess of no great size, being only 16 feet square in the clear, and square in plan. Such is the general disposition of the original fabric, as is evident from the bas-relief in a panel of the later shrine, where the Emperor is represented offering the model of his church to the Virgin. The inside has a lower range of arcades forming an aisle, above which is a gallery all round forming a second tier, the arcades being filled in with slender columns.‡ Above is a clerestory with windows, surmounted by an octagonal

* He built a palace at Mayence and another at Nimegen.

† In plan, section and decoration it resembles the Church of S. Vitale at Ravenna, following a type generally adopted at that epoch of Byzantine art. Both of them have been disfigured by plaister work in succeeding ages.

‡ Rondelet, vol. I, p. 254, mentions four columns of red oriental granite in the Salle d'Apollon of the Louvre, as having come from the tomb (or rather sepulchral church) of Charlemagne, at Aix la Chapelle; they are about

dome. The diameter of the centre octagon seems to be 47 ft. 6 in., or half the width between the outer walls of the polygon, which is 95 ft. in diameter in the clear. The total height, from the floor to the apex of the dome, is about 105 feet. The sacellum, or altar recess, and a portion of the external wall adjoining were, in the thirteenth century or about four-and-a-half centuries later, pulled down in order to form an entrance to a choir, or kind of Lady chapel, then built as an addition.

In front of the western, or main entrance, there was a square fore-court, anciently called a "Paradis," with porticoes and side halls, and facing the entrance were dwellings for the priests, similar to the arrangement of the Old Basilica of St. Peter's at Rome then existing, and there was a passage uniting the imperial palace with the church. Such were the general architectural arrangements of the building, the exterior of which was probably of a plain simple character; but the interior was profusely enriched with Roman† mosaics, like those of Ravenna and other churches of that period, which covered the plain faces; and there were handsome bronze doors, panellings, and gratings, as shewn in Weerth's work. The mosaics, however, have disappeared, and the interior presents the aspect of a degraded period of art.

Eginhard, in the Life of his father-in-law, Charlemagne (c. xxxi.), describes the tranquil closing scene of this great man's existence, and states, that after the completion of the funeral preparations, his body, accompanied by the grief of all the people, was carried away and buried. At first it was doubted where it should be laid, as, while living, he had given no precise instructions on the point. At length all were agreed, that he could not be buried anywhere with greater propriety than in that Basilica, which he himself had erected at Aix la Chapelle, for the love of God and of our Lord Jesus Christ, and in honor of the Holy Virgin. In it he was buried, on the same day that he died, and a gilt arch was built above the spot, with his statue and the following inscription: "Under this is placed the Body of Charles, the great and orthodox Emperor, who nobly enlarged the Kingdom of the Franks, and happily ruled 47 years," &c.

There are some who think that Charlemagne still sleeps on earth; but the myth properly refers to Frederic I. Barbarossa his successor, who is said to be seated deep below ground, in the Kyffhaüser-Berg in the golden meadow of Thüringia, with his generals at a stone table, through which his long red beard has grown, waiting for the restoration of one united German Empire.

These myths, wild and fanciful as they are, and common to the kings of other nations of remote periods, gain especial significance at this moment. It is now ten centuries and a half since Carolus died. Germany in the mean time has been broken up into many kingdoms, principalities, electorates and powers. Above half a century ago as mighty a conqueror had overrun Europe, and his power extended as far as that of the great Karolus. But it is vanished into air! I pretend not to prophecy nor to interpret the prophetic myth of the past. But who can say, if it be not now about to be realised in him who in defence of the fatherland, having overrun the kingdom of the Franks, is about to be hailed as Emperor of one united Germany by his brother sovereigns on the "Königsstuhl" of the Rhine—not Karolus, Magnus et Orthodox—not Barbarossa—but Guglielmus, Victor et Religiosus!

There are one or two circumstances connected with this interment, which are remarkable. The short interval which occurred between the death and the burial of Charlemagne was caused, perhaps, by the state of decomposition of the body, rendering dispatch absolutely necessary, although his son and successor, Louis the pious, was in Aquitaine, many days' journey distant. It seems therefore probable that the body was provisionally deposited, possibly in the sacellum or altar recess, with the arch over it to indicate its position.

16 in. in diameter, and 11 ft. 6 in. high; they were taken away by the French in 1794, as also the rest of those in the arcades of the Galleries; the latter, however, were restored to Aix in 1815, but were never replaced, and now lie about neglected.

† Eginhard mentions also gold and silver, with candelabra and marbles and columns brought frome Rome and Ravenna, which could not be procured from elsewhere.

The King Louis, when he arrived, had a proper place assigned for the tomb, as his historian, Nitard, states. Ademar, in his 'Historiarum,' libri II, c. ix, apud Pertz Monum. SS. IV. p. 118, described, towards the beginning of the eleventh century, the appearance of the Royal sepulchre. "Karolus was buried at Aix, in the Basilica of the holy mother of God, which he had himself built. His body was embalmed, and seated on a golden throne, placed in a bend (curvaturâ) of the sepulchre. He was girded by his golden sword, holding a golden gospel in his hands on his knees; his shoulders rested against (the back of) his seat; and his head boldly erect was bound to his diadem with a chain of gold. And in his diadem was placed a piece of the wood of the Holy Cross. And they filled his sepulchre with perfumes, pigments, balsam and musk, and much treasure in gold. His body was clothed with his imperial robes, and his face was exposed, in a napkin, under the diadem. And there was the goat's hair shirt next the skin, which he always secretly wore; and, over the imperial garments, the pilgrim's golden wallet, which he was accustomed to carry to Rome, and his golden sceptre and golden shield, which Pope Leo had consecrated, placed before him hanging down: and his sepulchre was closed and sealed."

It is impossible to doubt, as M. Arendt observes, the authenticity of this description, which is evidently by one, who had actually seen the tomb and its contents: and it is well known, that Ademar founded his history upon ancient and most authentic authorities, since lost, particularly the Annals of the Monastry of Lorsch.

We here find, that the sepulchre of Karolus was in a subterraneous chamber, in a vault, where the Emperor was seated on his throne; and a monumental part of the golden arch* was in the church above ground with the inscription given by Einhardt. Mons. Arendt considers that this latter portion disappeared at the end of the ninth century, in consequence of the invasion of the Normans, who, in 888, took possession of Aix-la-Chapelle, and reduced to ashes the palace of Charlemagne, which remained in ruin eighty years, until the time of Otho the Great. According to the chronicle of Hermann de Reichenau, the interior of the church was devastated and used as a stable by the Normans.

In the beginning of the tenth century the palace and the church were restored, and in 936 they were used for the consecration of Otho the first. The visible part of the tomb, that is the arch, was not restored, and the sepulchral crypt had been forgotten; for when about the year 1000, the Emperor Otho III. wished to visit Charlemagne in his tomb, no one knew where it was. He himself directed the operations for its discovery, and one of the great dignitaries of his court narrates the result (Cron. Novaliciense III, 32 ap. Pertz): "We therefore entered where Charles was. He was not in a recumbent position, as is the custom of the dead, but he was seated on his throne as though alive. He was crowned with a golden crown, holding his sceptre in his gloved hands. Over him was a vault strongly built of lime and marbles. We reached him by breaking open a hole, and when we got in smelt a great perfume. We adored him with bent knees, and immediately the Emperor Otho clothed him with white garments and cut his nails, which had grown so long as to cut through the gloves on his hands, and restored every thing wanting around him. But no part of his person had hitherto decayed, except the upper part of his nose, which Otho caused immediately to be replaced with gold, and having abstracted one tooth, he went away, and the vault was closed up again."

The body of the great Emperor remained in his tomb for 165 years from the time when Otho III. had visited it A.D. 1000, until the time of the Canonization of Charles in 1165 by Pope Alexander, by whose will and mandate in the presence of the Emperor Frederick, or Barbarossa, the bones of Charlemagne were taken up with the utmost reverence from the spot, where they had been 352 years.

* To shew that this was not an unusual arrangement, I give in the illustrations a drawing made by me of a small sepulchral stone found in the Syriac Cemetery, Rome, and preserved in the Museum of Antiquities in the Cloistered Court of S. Giovanni Laterano.

They were then honorably placed in a magnificent coffin* by Reinald Archbishop of Cologne and Alexander Bishop of Liege, and Charles was canonized and proclaimed a holy Confessor. Fifty years after, according to Reinald of Liege, the body of Charlemagne was placed in a more magnificent shrine of gold and silver, which was begun in the time of Barbarossa, and completed in that of his successor Frederick II. in 1415, and securely closed by that Emperor himself with great ceremony. Then was added by the town, and finished (1355-1414) a new choir, as shewn upon the plan, either to meet the increased necessities of public worship, and crowded pilgrimages caused by the canonization, and for which the original octagon was inadequate; or to carry out the greater cult to the Virgin Mary, as is evidenced also in many of the cathedrals and abbey churches of our own country, by the Lady Chapel extension at the east end. This increase corresponds in every particular structurally with that of the Temple Church in London, where the old Norman circular church has the early pointed elongation, so that the original western portion forms as it were a narthex or vestibule to the quadrangular area used for the services.

In the Aix la Chapelle addition, the eastern end is very effectively developed or expanded into a circle, forming a species of more glorious sanctuary for the altar, and upon it was placed the shrine with the relics of the sainted Emperor, which remained there during five centuries. It was opened in 1481, on the 12th October, upon the earnest application of Louis XI of France, who in honor of the Virgin and Charlemagne enclosed one of the arms in a golden case weighing 28½ marks of gold. This occurred in the pontificate of Sixtus the IVth, in the reign of Frederick the third, Emperor of the Romans, &c. &c.

After this, all memory of the remains of Charlemagne being contained in this shrine seems to have passed away, and the magnificent depository was supposed to contain the body of Saint Leopard, martyred under Julian the Apostate, and which body, imagined to have a greater odor of sanctity, had been transferred from Otricoli near Rome to Aix, and deposited in the Basilica of Aix, in the time of Otho III. Thus the Martyr had usurped the place of the sainted Emperor in the estimation of the worshippers. In fact, so utterly had the imperial remains been forgotten, that when about 1780, the ancient altar of the choir was pulled down and replaced by another in the style of the "Renaissance," the shrine with its precious contents was placed in a sacristy of the church, where its other sacred treasures are kept. The tradition alone remained of the centre of the polygon being the site of the tomb, and a stone was placed to mark the spot, as I have already said, at the beginning of the present century. The more recent publication of many chronicles and other authentic memorials of the Carlovingian epoch, drew the public attention to a more thorough study of all facts connected with the reign and person of Charlemagne; and Professor Bock, of Brussels, more particularly took up the question from the year 1837 as to the tomb of the great Emperor. His researches attracted the notice of the late King of Prussia, Frederick William IV, who directed steps to be taken to discover the original sepulchral crypt. Excavations were accordingly made in the atrium of the church, and on the right-hand side of the aisle of the octagon, and there were found various coffins, among which was that containing the body of Saint Leopard. In the centre of the octagon, where the body of Charlemagne had always been supposed to be deposited, were discovered the remains of a Roman water conduit, rendering it doubtful, whether it was possible for any crypt ever to have been there. With regard to the tomb of Charles the results were negative. But the inscription on the coffin of S. Leopard led to the conviction, that the magnificent shrine, supposed by popular belief for so long a period to contain the remains of

* There is much obscurity as to this receptacle of the imperial remains. There is preserved in Aix a tradition of a marble sarcophagus, carved with the representation in high relief of the Rape of Proserpine, and I am inclined to believe it was temporarily used on this occasion. It is called the tomb of Charlemagne, and was removed by the French to the church of the Benhardine Monks in Marseilles according to Dittmar's history of the World.

that Saint, must be the deposit of some other precious relics. On the 7th of August, 1843, the shrine was opened in the presence of a deputation of the Chapter and two physicians, and inside was found a parchment reciting in most formal terms the fact "*ad futuram rei memoriam*" of the opening of the shrine in 1481, the abstraction of the right humerus, and its being incased in gold by Louis XI. Underneath was a tissue* of purple silk of great beauty, enveloping bones forming a complete skeleton with the exception of the skull, the upper right arm, and a tibia, which are now in the treasury of the Basilica, and thus were recognised the true remains of Charlemagne.

As I have said, these excavations produced no evidence as to the sepulchral chamber, and the curiosity of archæologists and antiquarians had not been satisfied. In 1861 these researches were renewed with the permission of the Government, under the superintendence of his Excellency Baron d'Olfers, and the direction of the architect of the cathedral Herr Zweiner, both of them our Honorary and Corresponding Members, assisted by the town architect. They first dug down to depths varying from eight feet and a half to eleven feet in every direction, under the centre and to the right and left. They found masses of solid masonry two feet thick running in various directions, not in the axis of the buildings, and some stone coffins, but no evidences of a crypt or vault, or hollow space. There were traces of construction apparently antecedent to the Basilica, probably Roman, foundations of the original construction in and next the old choir, and cut away to receive it, and at 11 feet deep a spring of water.

It hence appears probable, that the original sepulchral vault was destroyed, when the body of Charles was taken up in 1163, about three centuries and a half after his original interment, and the hollow filled up so as to leave no trace of any previous interment: and this may possibly have been necessitated by the fact, that in order originally to gain sufficient height for the vault, the platform over it, on which the altar stood, may have been raised perhaps a couple of feet above the general level of the floor, with steps up to it from the aisle in front. Hence to have a level floor from the octagon to the new Gothic chapel or choir, this must have been removed.

Upon considering then all the facts, of which I have endeavoured to give you a brief, yet correct summary, my own impression is, that, in conformity with the practice of that and subsequent periods of mediæval religious observances, the body of Charlemagne was originally preserved in a vault built under the high altar in the square recess at the east end, now destroyed, but between the central octagon and the new choir. It was anciently the custom to place the bodies of saints, martyrs and other eminent confessors of the faith and founders immediately over or under the altar, in front or as close to it as possible. Thus, in the Basilica of S. Ambrogio at Milan the altar has a baldachino or canopy over it supported by four columns, and on the top of the baldachino is placed the shrine of the saint. At the Cathedral in the same city, the body of San Carlo is superbly entombed with its silver coffin in a crypt under the high altar, a very frequent arrangement in Italy. And throughout that country are instances of the very altar itself being a sarcophagus, occasionally with a crystal front, exposing the very mummy corpse of the saint. In our own land the shrine with the body was often behind the altar screen in a special sanctuary, where the pious might worship the sacred remains at all times and in greater numbers, as in Westminster Abbey, S. Albans, Canterbury, Winchester, &c. &c. Consequently I do not think that the body of Charlemagne could have been deposited in the centre of the octagon: for, independently of the evidences "*in loco*" to the contrary, it is too remote from what was and is considered the most holy part of the sacred fabric. Particularly when we regard him as the ruler over so vast a portion of Europe, the sanctity attributed to him as the Defender of the Head of the Church, which was confirmed by his subsequent canonization, and as the founder of the Cathedral. Therefore under or immediately

* Mons. Michel alludes to this tissue in his learned 'Reserches sur le commerce, la fabrication et l'usage des Etoffes de soie.' Paris, 1852-54. 8vo.

before the altar I apprehend it was, that his body originally was preserved; and only removed when in the time of Otho III. he was canonized, and the more recent choir being erected to give greater splendour to the worship of the Virgin, the remains of the sainted monarch were transferred to a more befitting receptacle and reliquiry of that period, in order to place them over the new altar.

I have hitherto mainly alluded to the structural depository of Charlemagne; but there are other interesting circumstances connected therewith, which cannot be passed over unnoticed. In the description of the tomb, when opened in the eleventh century, given by Ademar and already alluded to, we find mentioned the golden throne, his sword, the golden gospels, his diadem and chain of gold, a piece of wood of the holy cross, the golden pilgrim's satchel, his golden sceptre and shield, before him placed "*dependentia.*" He sat, in fact, in all the pomp and splendour of a living monarch. His spirit had departed and was with the God who gave it; but the gorgeous appendages of human splendor encircled the corpse of the dead. These doubtless were taken up on the occasion of the removal of the body by Otho III. A portion of these are religiously preserved in the Sacred Treasury of the Cathedral; First of all there is the famous silver-gilt chest or reliquary weighing 390 lbs. containing the bones, its length is 6 ft. 10 inches, its breadth 2 feet, and its height 3 feet 1½ inch. The sloping top has eight panels containing bas-reliefs, which represent eight incidents in the life of Charlemagne. One especially, the presentation of the model of the church by him to the Virgin. In another he is kneeling before an altar, near which stands a priest handing to an angel a scroll, on which are inscribed the remarkable words "crimen (not peccatum) mortale," as though the uxorious king were confessing the sin of his many wives and concubines, which tarnished his otherwise noble character. There are sixteen niches on the sides with as many German emperors or kings, as Charlemagne, Louis the Pious, Lothaire and Zwendebol, as the Othos I, II, III, IV, Henries I, II, III, IV, V, VI, and Frederics I and II, holding a sceptre in the right hand, and globe or a book in the left, with the title Emperor or King of the Romans, as might be, inscribed on the arch above each. The whole is embellished with precious stones, cameos, &c., and on the ridge are five large balls of great value.

2. The cranium of Charlemagne, contained in a bust of silver gilt, 3 feet high, covered with enamels and enriched with stones and gems. The head has on it the imperial crown, with 71 precious stones.

3. The right arm* in the silver gilt case given by Louis XI.

4. The ivory hunting horn of the Emperor.

5. The marble throne on which the body sat in the vault from 814 to 1165. The plates of gold which covered it are also preserved.

6. A tibia of Charles.

But the following reputed relics may be supposed to be, in the estimation of devout Roman Catholics, indisputable evidences of the piety of the Great Emperor, as part of his sacred treasures, and many of them constantly worn about his person while alive, as also in his grave: 1. A piece of the true Cross! 2. The leathern girdle of our Lord, on which may be seen the impression of Constantine's seal! 3. A lock of the Virgin's hair! 4. The cord that bound the rod, which smote the Saviour! 5. A nail of the cross! 6. The sponge which was filled with vinegar! 7. Some manna of the wilderness! 8. Some bits of Aaron's rod; besides the arm of Simeon, on which he bore the Infant Jesus, and some of the blood and bones of S. Stephen! It was upon these traditional relics, comprehending also the very key of the Tomb of Calvary (!) given by the Patriarch of Jerusalem, that succeeding Emperors of Germany were accustomed, with great veneration and respect, to swear at the coronation ceremonies, crowned with the diadem and girded with the sword Joyeuse.

* The questionable authenticity of such relics is curiously illustrated in this case, as the supposed arm is stated no surgical authority to be a thigh bone. See also Baedeker, 'Rhine and Northern Germany,' Aix la Chapelle.

All these relics, have, at various periods, been removed to places of safety, as in 881-1236, and in 1656; on the occasion of an invasion, or to save them from fire. In 1794, at the time of the French Revolution, they were removedto Paderbon, and replaced in 1804, when Napoleon I had restored order. On the demand of the Emperor Francis II of Austria, in 1794, the sword Joyeuse, and various relics, were sent, as to a place of safety, to Vienna; where they still remain, to the great mortification of the Chapter, who hope some day to see them restored to the Cathedral of Aix, by the generous disinterestedness of the Emperor of Austria.

All the authorities relating to the tomb of Charlemagne are to be found in the following works in the Institute Library. The 'Algemeine Bauzeitung,' plates and text, 1840-41; 'Ernst aus' M. Weerth Kunstdenkmäler des Christlichen Mittelalters in den Rheinlanden,' plates and text, 1857, *sub voce* Aachen; and Arendt 'Des recherches faites dans la Cathedrale d'Aix la Chapelle pour retrouver le tombeau de Charlemagne,' 8vo., 1862. There is also Haagen's 'Karl's des Grossen letzten tage und grab:' and a small octavo by F. Nolten, 1818; and Dr. Bock's 'Das Heilighthum zu Aachen.'

TOMB OF WILLIAM THE CONQUEROR.

I cannot forbear, in conclusion, alluding to the remarkable circumstances attending the burial of another great King, William the Conqueror, first of England, as mentioned by Thierry in his 'History of the Conquest of England.' "The inhumation of the great chief, *the famous Baron*, as the historians of the period style him, was not completed, without fresh incidents; (after his corpse had been abandoned for several hours by his family, his nobles and attendants). All the Bishops and Abbots of Normandy were assembled for the ceremony, they had prepared the grave in the church between the choir and the altar; the mass was finished; they were about to lower the body, when a man advancing from the crowd said aloud, 'Priest and Bishops, this land is mine: it was the site of my father's house; the man, for whom you are now praying, took it from me by force to build his church upon it. I have not sold my land; I have not pawned it; I have not forfeited it. In the name of God, I forbid the body of the spoiler to be placed here, or to be covered by my glebe.' The man, who thus spoke, was Asselin Fitz-Arthur, and all present confirmed the truth of what he had said. The bishops made him approach and agreed to pay him then and there sixty pence for the immediate place of sepulture, and to give him equitable recompense for the rest of the land. The king's body was without a coffin, clothed in its royal habit; when they proceeded to place it in the grave, which had been constructed in masonry, the aperture was found to be too narrow; forcing the body in, it burst! They burnt abundance of incense and perfumes, but in vain; the people dispersed in disgust, and the priests themselves hastening the ceremony soon quitted the church." Ultimately a costly monument was erected over the grave by William Rufus.

Centuries passed away, and, in 1562, in reprisal for bloody cruelties committed by the Roman Catholics, the conventual buildings were well-nigh demolished by the Huguenots; the rich vessels and plate were melted; the choice relics, including, among others, one of the stones with which S. Stephen had been stoned, were scattered to the winds; and the tomb of King William was broken open in search of concealed treasure! Then the remains of the mighty monarch were cast forth, and only one thigh-bone, somewhat larger than of an ordinary man, was recovered. It was sealed up in a leaden box a few inches in size, and deposited once more in the ground, under a tomb twice subsequently demolished! This bone, covered with a flat slab having an inscription, is all that bears witness to the fact, that the unconquered conqueror, the Duke of the Normans and King of England, the founder of S. Etienne de Caen, rested there! SIC TRANSIT GLORIA MUNDI!

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COMMUNICATION FROM Mr. H. L. FLORENCE, Travelling Soane Medalist of the Royal Institute of British Architects, respecting THE DESIGNS FOR THE COMPLETION OF THE ELEVATION OF ST. PETRONIO AT BOLOGNA.

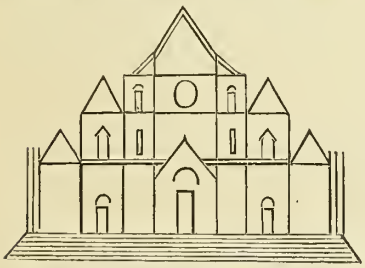
Bologna, *6th August*, 1870.

Dear Mr. Donaldson,

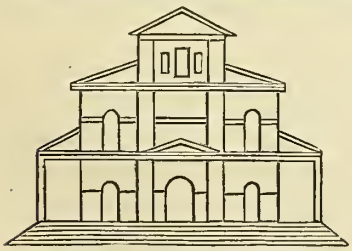
I beg to enclose you a List, and some particulars of the Designs for the completion of the Façade of St. Petronio in Bologna, which you requested me to procure. I am sorry that I have not been able to do so earlier, but have only just arrived here for the first time.

The Drawings are hung up so high, and the room is so very dark, that, although I had the assistance of a ladder, I am obliged to leave several drawings without any remark; they are also hung without any regard to number or order.

In regard to the style, also, although Italian Gothic seems to be the most applicable term to apply to most of the designs, many of them, although the general forms are Gothic, are yet very Renaissance in character. I can scarcely think that any of them are very satisfactory, but have marked with a star those I thought best.



The general outline of nearly all the Gothic Designs is, more or less, similar to this, which is No. 4, one of Vignola's and one of the best.



The best Classic Italian one is, I think, by Palladio, No. 18, of which this is the outline.

Hoping that these notes may contain the particulars you required,

I beg to remain, Yours very sincerely,

H. L. FLORENCE, *Travelling S.R.A.*

N.B.—This paper supplies an omission, alluded to by Professor Donaldson in his communication in the Transactions of last Session, 1869-70, page 110.

List of Drawings copied from that in the Vestry of St. Petronio, Bologna.

1. Terribilia.*
2. Bald. Peruzzi.
3. Ditto.
4. Vignola.*
5. Ditto.*
6. Domenico Tibaldi.
7. Alberto Alberti (da Borgo Sepolcro).
8. Giulio Romano.
9. Ditto.
10. Anonymous.*
11. Ditto.*
12. Ditto.
13. Baldassare da Siena (Peruzzi).
14. Anonymous.
15. Ditto.
16. Girolamo Rainaldi.
17. Domenico Aimo.
18. Andrea Palladio.*
19. Ditto.
20. Terribilia.
21. Friano Ambrosini
22. Egidio Berdoni.
23. Domenico Caisine.
24. Anonymous.
25. Ditto.
26. Giulio Romano (and Cristofero Lombardo).
27. Domenico Aimo.
28. Giacomo Ranuzzi.
29. Mauro Tesi.
30. Prospero Reni.
31. Baldassare da Siena (Peruzzi).
32. Carazzoli.
33. Anonymous.
34. G. Rainaldi.
35. Ditto.
36. Ditto.
37. A. Palladio.
38. Ditto.
39. A. Scarselli.
40. Mauro Tesi.

I am unable to give you any dates, as none of the Drawings I could see have any date affixed, and I could not succeed in obtaining information respecting them.

Also, I find it impossible to group them; there is no order in the hanging, and I cannot do more than guess, to which of the elevations the plans and sections belong.

1. Terribilia; elevation Italian Gothic; five gables, with pinnacled buttresses; rose windows over aisle doors, central three-light window.* Published by Cicognara.
2. Large section; dome and lantern; Italian.
3. Elevation and plan above; late pointed; five-light central window, three-light side windows, central gable, flat aisle, gable steep, 2 and 3 B. Peruzzi.
4. Vignola, one of the best.*
5. Ditto, more Classic in character.*
6. D. Tibaldi; panelled and fantastic gables, three rose windows, outline similar to No. 4.
7. Alberto Alberti; Renaissance; present doorways removed, Venetian windows, three stories to nave.
8. G. Romano; large elevation and side ditto.*
9. Similar in arrangement to No. 4; classic order to lower portion.
10. Gothic three-wheel windows, five gables; one of the best.*
11. No. 4 arrangement, much panelled, two-light window under round arch over each door, round windows in gables.*
12.
13.
14. Section.
15. Section.
16.
17.
18. A. Palladio; doors in part retained.* These
19. are all very similar, No. 18 the best; also
37. No. 38. Two elevations are published in Bertotti Scamozzi's edition of the works of Palladio.
20.
21. A print; section.
22. Plan.
23. Ditto.
24. Ditto.
25. Ditto.
26. G. Romano and C. Lombardo; Classic order, pointed windows, Campanile at north angle; dome shown at crossing.
27.
28. Renaissance, two orders.
29. Altar and Baldachino.
30.
31. Gothic; large central rose window, three-light over each side door.
32. Carazzoli; section.
33. Plan.
34.
35. Elevation; mixed gothic.
36. Section.
39. Section; print.
40. Somewhat German in character.
1. Model only; Arduins Riguzzi, 1514; Gothic, completed with transepts and central dome, and central gable flanked by two towers to each transept. The west front the least imposing. Dome octagonal and gabled.

* See Milizia's observations on these designs in his lives of these architects. Valery, 'Voyage en Italie,' gives the names of two other competitors, Varignana and Andrea da Formigine, who perhaps may be the authors of some of the anonymous designs.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, 9th January, 1871, THOMAS H. WYATT, President, in the Chair, the following Paper was read:—

RELATIONS OF GEOLOGY TO ARCHITECTURE,

(SECOND COMMUNICATION.)

CONSIDERATIONS ON THE SELECTION OF BUILDING SITES.

By Professor D. T. ANSTED, M.A., F.R.S., For. Sec. G. S., Hon. Mem. R.I.B.A., &c.

IN a former communication I pointed out some of the facts relating to the application of geology to architecture, but I limited my remarks on that occasion to the subject of building material. I desire now without further preface to give some account of another relation between these two sciences, in the hope that I may be able to make a few suggestions of practical value, illustrating the importance of regarding the structure of the earth and the nature of the rocks when it is intended to make use of the surface of the earth as a basis of operations for important architectural constructions.

If it were necessary to give illustrative proof of the value of such considerations, I could not do better than remind you of those remarkable leaning towers in Pisa and Bologna that have sometimes puzzled travellers. I might also mention the Cathedral of Pisa close to the leaning tower, as an instance of a noble specimen of mediæval architecture, in which there are no horizontal lines and no vertical lines, and indeed, no straight lines, owing to a neglect of knowledge as to the nature of the foundations on a shifting alluvial bottom.

The extent to which these fine buildings are injured by this neglect, which may almost be said to have reduced noble specimens of art to mere curiosities and toys, is not a subject to which I mean to do more than allude. It is quite true that with modern appliances doubtful foundations may be converted into good ones; but while we appear to have a case of perfect success in this endeavour, in the Greenwich Railway Viaduct and the Pimlico Bridewell, I am afraid the crushing of the granite columns which support the Holborn Viaduct* shows that such appliances are not always enough to render a mass of alluvial sands and gravel resting on a lower mass also of alluvial origin, fit to bear every kind of structure that may be put upon it.

The selection of a site is not often left to the architect, but it is certain that his work ought to be greatly influenced by it, and that his opinion should be sought and his advice duly weighed before the site is decided on, or at least before the nature of the construction is altogether fixed. But, if this is so, it is clear that his education should enable him to give such attention to this subject as to justify him in reporting on it in all its bearings, and from every point of view, and should enable him to take into consideration both general and local conditions. Among these the geological conditions ought not to be forgotten, for they will infallibly influence the cost of building, the sanitory state of the future building, the methods available for improving what is unsatisfactory, and making the best use of natural capabilities, and according to the nature of the exposure they will affect even the permanence and durability of the building. I include, in speaking of geological conditions, some which perhaps more properly belong to physical geography, but there will be no need to draw a distinction between them on the present occasion.

* This remark was made under a mis-apprehension of the case referred to, and was subsequently withdrawn. (See pp. 57 and 58).

I venture to say that the site and the natural conditions of the site should to some extent determine the style of the building, the plan of the various substructures, and the uses to which they may be applied. The material to be employed also requires to have reference to these points, while the contrivances for drainage and (except in large towns) the nature of the water supply must be modified to meet the local geological peculiarities of soil and rock.

It will no doubt often happen that one or more of these are fixed beforehand, and are independent of the architect, but he should be able to adapt the rest so as to take the best advantage of circumstances. In no case can geological considerations be safely neglected.

I propose in this Paper to point out and illustrate as far as may be, some of the more important of these relations of science to the art of building.

If you consider the origin and growth of architectural styles, and the conditions under which the best and most deservedly admired works, whether of ancient or modern art, have originated, you will not question the correctness of my assumption that there is a close relation between the science I represent, and the art you practise. The pyramids of Egypt rising from the dead level of the Nile valley, and the temples of the same country, cut out of solid rock, exhibit adaptations of style to the material available and to the nature of the site based on the strictest and soundest judgment. Pyramids constructed in Egypt of brick or limestone are fit monuments for sandy plains, and seem to require a vast expanse to justify their severity and formality of outline, and their total unfitness for decoration of any kind. Rock temples, whether in Egypt or India, are immediate results from geological conditions. Impossible, except in similar positions, they possess, owing to their adaptation to local circumstances, a simple grandeur containing elements of the highest beauty.

To perceive the growth of architectural taste and the history of classical styles, we must refer to the geological conditions as well as the climate of the country where these styles originated. In Greece limestone of a creamy white or grey tint is the prevalent rock, and the limestone forms a plateau intersected by ravines reducing the surface to a number of flat-topped hills of no very great elevation separated by rocky valleys. Owing to the long continued action of the weather the limestone rock is much broken at the surface, and loose blocks of all sizes abound everywhere. In many places the whole of a hill-side is apparently made up of loose stones, naturally squared and resembling a broken wall. Under such circumstances square forms, upright columns and walls with rectangular openings are inevitable. The earliest constructions in such a country must have been, as we find they were, caverns with square entrances, built of such stones as were lying about. After these came the Cyclopean structures, often described, and very familiar to the architect and the archæologist. Out of such buildings grew the earliest forms of cultivated art and the elements of all the classical styles in architecture. In the Island of Ithaca, the buildings known as the School of Homer and the Palace of Ulysses are especially illustrative and instructive. In Cephalonia are other examples, especially in the remains of ancient Samos, and both on the main land of Greece and in the Morea there are many similar instances. The towns were built for protection on the hill sides, and on the hill top was the temple and the Acropolis. The valleys were cultivated, and for the most part, no doubt, the people lived in them, except when their safety was endangered by the approach of an enemy.

The necessity of constructing the temples and great public buildings on elevated sites, where they would stand out boldly against a clear sky and be seen through an atmosphere of exceptional purity and dryness; the necessity also of using as material the rock under foot, or the marble in adjacent quarries, the facility with which rock and marble could be chiselled into form, and perhaps some reasons connected with the history of the Greek people and the sources whence their inspiration was drawn, must have contributed largely to the formation of those classical styles prevalent wherever Greek civilization penetrated.

On the other hand, the cradle of Gothic art being in the north, in a colder climate and gloomier sky, and the development of that form of art being in countries where the surface consisted of wide river valleys or great forest-covered plains, where roofs were necessary and where elevation was needed to give effect to a building, the constructive material at hand consisting largely of wood, and the stones available including a great variety both of limestone and sandstone, the art of construction took a different direction and adapted itself to these very different conditions. The limestones of the north are very different from those of Greece, and exposed to the weather they change much more. Then natural conditions, added to the difference in race, and all mutually influencing each other, have produced the peculiarities of Gothic architecture as the natural conditions in Greece resulted in the adoption of classical styles.

I will not detain you longer by preliminary remarks, except to remind you that Indian and Chinese architecture belong also to the country, the climate, and the people where they have originated, and that many singular varieties of style, especially those adopted in Spain and Portugal, as well as the various Italian schools of architecture might, without much difficulty, be shown to be derived from or at least greatly affected by the soil and climate, and the material at hand for building. In art as in nature there is a process of natural selection which is the real governing principle of all varieties; there is an incessant battle to determine what novelty shall take possession of the field, and to what extent the old and recognised species shall be superseded by some new modification. Every country and every century has its own special characteristic, but the groups are determined to a very great extent by the country, rather than by the races. The *genius loci* manifestly affects the result.

The nature of the rock greatly influences the soil and subsoil, both of which are derived from the rock, either directly or indirectly, and must therefore have some effect on the buildings constructed on the surface. This is the case partly as involving the question of foundations, partly as being closely related to the methods of under-drainage generally required to secure the stability as well as the healthiness of the site. The architect is no doubt less dependent on the rock than the engineer, but he cannot safely neglect it. In my work on geology, published so long ago as 1844, I pointed out the importance of considerations of this kind, and although then a very young man, ventured to offer some practical suggestions in reference to it. Since that time I have had constant experience in these applications of geology—much more, no doubt, in engineering than architecture—and I have often had occasion to regret that some knowledge of rocks did not enter as a matter of necessity into the education of all architects and engineers.

Rocks may be conveniently grouped into several divisions so far as they affect towns, public buildings, and private residences, and it must be remembered that in most cases the architect has to deal, not so much with the rocks themselves as with the weathered and often rolled fragments derived from them. There is in most parts of England, and generally in northern Europe, a superficial mass of moved material and soil masking the real underlying rock, and this is often so thick that digging for ordinary foundations does not get through it. Such material may, with due precaution, be safe enough, and it generally is; but there are cases where it certainly is not, and these should be understood. They can only be understood by one who has at least made himself acquainted with the first outlines of geology as regards the stratification, upheaval, and dislocation of rocks. In some countries, and in some parts of our own country, the rocks are at the surface, and then the whole question is easily decided; but when this is not the case, a knowledge concerning them can only be obtained by studying a little the science that deals with them.

Certain rocks, hard and compact in themselves, are so far fissured and broken as to allow water readily to pass through them. Parts of the millstone grit and of the new red sandstone among sandstones,

the oolites and parts of the carboniferous limestone among limestones are of this kind. They are rocks not, perhaps, themselves absorbent, or only partially so, but very permeable, owing to their mechanical state. On such rocks foundations are of course secure, and drainage is good and easy. If such rocks can be reached, they are safe under ordinary circumstances so long as they are horizontal; but if they are in strata inclining towards a valley, and the construction proposed is near or upon the slope, it is not seldom that additional drainage, and the weight of a building combined, may produce a slide, which will show itself in cracked walls and unsound foundations. Instances of such accidents are not rare. They may generally be foreseen, and to some extent provided against, by checking drainage between the strata, especially when the strata of stone are separated by films of clay, or by thin belts of sand. But they can only be known and prevented by the aid of that small amount of practical geology I desire to recommend.

Non-absorbent rocks, such as crystalline limestones and very compact grits and sandstones, are often so cracked and fissured as to let water drain into and amongst them, and in that case they are not often unhealthy. It is only when they have no outlet, so that the entering water stagnates in the rock till it evaporates, that they are likely to be injurious. I had an opportunity of observing a case in the island of Corfu some years since, in which a particular valley was entirely destitute of inhabitants, though it appeared in every way desirable, and at the time of my visit, in the spring months, was perfectly healthy. There was then a swampy bottom, but no miasma. I was informed by the people living near that a little later in the season the swamp dried up, and that soon afterwards miasma would begin to form, and would continue with a perfectly dry surface till the autumn rains set in. In this case the water could not run off underground, but though possible such conditions are exceptional. It is usual for hard limestones to be fissured and cavernous, and comparatively rare to find any large extent of such rock without a ready escape for water; but on the other hand, compact sandstones, quartzites, schists, and other metamorphic rock and granites are very usually impermeable in every sense. The water is either retained on the surface, or runs off the surface; the mass of the rock—though not without receiving a small amount of water, which circulates at all depths through the agency of such fissures as exist—being practically unaffected by surface drainage. It will be evident that if the rocks, whether limestones or sandstones, or indeed of whatever nature, are not stratified, there will be nothing but fissures to carry off entering water, whereas in the case of stratified rocks much depends on the direction and amount of the inclination of the beds, and much also on the material occupying the spaces between strata. In these matters, which may be of real importance in planning and estimating the cost of a building, and also in determining the fitness of a site, the rocks must be consulted, and their language must be understood.

The case of clay greatly resembles that of compact hard rocks which are non-absorbent, except that certain clays can be depended on as uniform in texture, while certain others cannot. The clays bedded regularly, and alternating with other rocks, are simply impermeable. For certain purposes they afford excellent foundations, and may be safely trusted. The same is the case with shales, which are altered clays greatly indurated, and not working up easily into mud, but stratified either with other shales or with sandstones. It must, however, be remembered that shales very easily and rapidly weather on exposure to the air, and that what appears to be a hard rock only to be removed by blasting while in the earth, will often be reduced in a few winters into a mass of minute fragments converted into mud, and washed away by the first shower.

But though much important and useful information may always be gained by the practical man by studying the condition of the rocks, their nature, and their relative position, it is in reference to what are called superficial deposits that a familiarity with the history of deposits is most generally available.

Buildings are of course constructed on all kinds of sites; but for many reasons modern towns generally occupy valleys, and are thus distinctly contrasted with towns of other days, which were much more commonly, and for equally good reasons, perched on eminences. Valleys traversed by rivers are far more convenient than plateaux, as more accessible both by land and water, and if less safe in a military sense than plains in some respects, they are much more so in others. But whatever the reason, it is a fact that all important and large cities are on or very near large rivers. Thus the condition of the rocks on the surface of valleys has important significance.

It may be assumed, in the present state of geological science, that all such open valleys as now form or contain the beds of rivers have been reduced to their present shape and have derived their present condition from the passage of water through them. The beds or bottoms of the valleys have been cut out by water, the transported material with which they are covered has been moved by water, the cliffs or slopes of the enclosing hills, at whatever distance, have been brought into their present state by weather action, and small as the stream may be that runs along a narrow channel in a winding course between these cliffs or slopes, it has been sufficient in the course of time to bring about the result we see before us. All that lies immediately beneath the surface in the valley often to a great depth consists of material removed very gradually by this water, while below that there is often another deposit of water-transported material, consisting of clay, stones, and sand, due perhaps to ancient glaciers, or left behind by icebergs that have floated over or have been stranded upon it when many fathoms below the sea level. Sometimes there are streams entering the main river from side valleys, and each of these again has formed its channel and left its mark. The more sluggish the main stream, and the further it is from its source, the greater in proportion is the effect of such feeders. When they are torrents they sweep all before them, and deposit large stones with smaller gravel, clay and sand. When they have had a more even course, they deposit fewer large stones and more mud and sand.

From this account of the history of river deposits, given in a very few words and requiring to be varied in detail for every stream without exception, you may understand the nature of the material that you have to deal with in preparing foundations for a large and massive construction, in almost every part of England where such buildings are likely to be erected. The clay you find may be alluvial clay deposited by the stream, or it may be boulder clay left behind by ice. It may thin out at any point, and give place to gravel, to loose stones, or to fine sand. Beneath it may be a quicksand. A certain number of tons pressing on the square foot of surface may and will cause the clay to slip away from the sands, or the run of an open drain through such sands may, by removing them, remove all support. When in the bed of the main stream, there may be a very regular deposit of clay, capable of supporting any weight that could be put upon it, but the intervention of one of the old and forgotten tributaries may have cut away part of this clay for an interval, or prevented its formation, and thus one part of a building may be on a good clay and another part on loose shifting sands.

It is exceedingly important that the exact physical conditions of the formation of the alluvial beds of rivers should be clearly understood by practical men. It is by no means the case that the present bed of a river is the only part where loose and uncertain material exists, nor is it at all necessary to assume any change of level, still less any great convulsion of nature, to account for the phenomena. They may be studied in every valley where the stream is left to take its natural course; but in England, and in many other countries where land is valuable and cultivation carried on extensively, the rivers are never left to themselves, and therefore the changes that explain and illustrate these conditions are not perceived. In a natural state a river rarely follows the same course through its valley many seasons in succession. Either it chokes up its old bed and steps aside to form a new one, or, owing to a torrent, it cuts itself a new course altogether, and leaves the old bed dry. All our river beds have been formed

in this way. It is not that the quantity of water brought down varies very much, but that the circumstances change, and new channels are cut, the deposits of course shifting. The whole width of the valley through which a river runs is of the same nature, and the deposits are due to the same cause. Hence the variety in the foundations in different parts of a valley far removed from the present course of the stream, which has not perhaps been allowed to shift for many centuries.

But in addition to ordinary alluvial bottoms resting on clay, limestone, or sandstone, as the case may be, and consisting of the usual admixture of sands, clays, and river gravels, are the instances in which the river valley has been ploughed out by the action of ice, and has received large deposits of boulders, boulder clay, and the usual accompaniments of fine and coarse sand and gravel. Gravels are frequently found at levels very much above the bottom of the valley, and they not unfrequently even cap the hills through which the river is cut. The same kinds of gravel often occupy the valleys themselves.

Excellent as gravel is as a foundation when in sufficient quantity and uniform in texture, it can hardly be trusted unless its history be known. The gravels called diluvial are often comparatively free from loose sands and clays, and are then excellent for every purpose required by the architect or engineer. They are sound, well drained, healthy, and generally yield water at a small depth. But it is not so with the gravels occasionally found with boulder clay, nor with ordinary river gravels, and thus, as I have already pointed out, the history of gravel is an important enquiry when it is proposed to construct buildings upon it.

Natural drainage is very important in all large buildings. Without this, even if the foundations are sound, moisture will rise up by capillary action through almost every variety of stone and brick, and will in time deface the building and increase the action of weather on the surface. Certain rocks drain naturally, and are safe. Others may be drained with little difficulty, and may be made safe. Others, again, will tax the ingenuity and experience of the most accomplished architect, and will, after all, be only partially cured. There cannot be a doubt that in this latter, and also in the second case, the constructor would be greatly assisted by knowing the nature of the enemy he has to deal with, and this can only be done by a knowledge of rocks generally and of the local geology.

Very important questions arise in reference to the relative influence of certain rocks, on the sanitary condition of the buildings erected upon them. Thus, in a general sense, it may be considered as proved by experience that clay soils and other impermeable material near the surface are less healthy than well drained sites, and more liable to attacks of fever, and that permeable soils and gravel are dry and healthy. There are, however, important modifications of this view dependant on the subsoil and underlying rock which are often out of sight and below even deep foundations, and here a knowledge of geology becomes necessary to the architect. It has been shewn by Professor PETTENKOFER, of Munich, that in certain cases where bands of clay intervene in gravel, the presence or absence of fever in the population of a town corresponds exactly with the existence or otherwise of these impermeable deposits. In other words, even where the general subsoil enjoys a certain amount of natural drainage, the healthiness of the site depends strictly on the condition of the rocks at a considerable depth, and that stagnant subsoil water, even when its presence cannot be detected by ordinary observation, makes itself felt in a very serious manner.

In speaking of the applications of geology I have avoided the mention of particular rocks as much as possible, because it is not so much the rock as its condition that affects the practical man. I have known granites porous and absorbent limestones compact and non-absorbent, sandstones offering every possible variety in every respect, and even clays very different in different places. Few are worse than the London clay in certain localities. What is wanted is such a general acquaintance with the

principles of stratification and the nature of rocks as shall enable the architect or builder to make the best use of the conditions he has to deal with. I cannot lay down rules that can be made use of without further trouble. I can only point out the key which will unlock the difficulty in each individual case, if it is applied properly and intelligently.

Water-supply from springs either at or moderately near the surface is a very essential matter in the case of buildings intended as habitations removed to some distance from pure running water. But it is now well known that however pleasant clear spring water may be to the taste, it is capable of containing and does in certain cases contain injurious ingredients sufficient to render it a fatal poison. There can be no doubt that certain superficial deposits and certain rocks are liable to induce this state in the water, while others are not. It is evident that the causes of events of this kind should be known to the architect, and it is highly desirable that he should be acquainted with the theory of springs, at least of such as are likely to affect buildings. Absorbent gravels resting on non-absorbent rocks may be expected to introduce poison into water when the ground is liable to be covered with decomposing animal or vegetable matter, or with sewage, for the rain entering them cannot fail to carry in water loaded with as much of such impurities as it can contain. Such of them as are soluble in water will certainly therefore mix with it and render unwholesome all the water pumped from the bottom of such a deposit.

On the other hand, where water has a free exit from rocks, it is almost impossible that such injury can take place to any great extent. Land springs and Artesian springs from basins are dangerous. Springs from hill sides or Artesian springs reaching water tapped in its progress to an outlet are generally safe. How is it to be known what is the nature of the springs without some reference to the science of geology, and some knowledge of the laws of superposition of rocks?

The whole subject of the weathering of rocks deserves the careful study of all who have to deal with stone and brick. All material without exception is affected by exposure, but while some will remain almost unchanged, and even hardens when left to the action of the air, other kinds will at once decompose and rot. It is not always the hardest that is the best. This is especially the case with flags or stones splitting with parallel faces. Many very good flagstones are formed by the exposure of quarried and squared blocks during one winter, after which in the following spring the mass may be split very easily by wedges in the cracks indicated. If left longer, however, they can no longer be split with advantage, and after a time it becomes impossible to split them at all. Something of this kind happens with all stones. After being quarried, stones are for some time in the state called green, retaining what is called the "quarry water," and after exposure to a certain extent they are said to be seasoned. In the latter state they are regarded as fit for use, but after all it is doubtful without experience whether they will be permanently sound. It is evident that if the architect and builder knew more of the history of stones he would be able to use them to better advantage.

The study of stones in the quarry, and a careful examination of the effects of weathering and disintegration by the action of rain and frost of the same stone in the immediate neighbourhood, whether naturally exposed or placed in buildings of any kind, combined with a knowledge of the chemical composition, the peculiarities of aggregation, and the natural history of the stone itself and the beds with which it is associated, will very often suggest to the intelligent observer the probable weak points of the stone for the special service for which it is designed. There are accumulated stores of information of this kind that should be familiar to all who have to decide on the selection of a stone, and it should be remembered that stone is in the nature of things an altered form of a very miscellaneous deposit, and that without especial care in selection and placing it is next to impossible to secure a large quantity of perfectly even quality.

You will observe that I have included a great variety of details as belonging to the very important subject of building sites, but I trust you will not think that I have done so without sufficient reason. I am well aware that in modern constructions beds of concrete play an important part in forming artificial foundations and are much relied on for keeping out damp and preventing unhealthy miasma. I wish to point out that however useful such an avoidance of the difficulty may be, it should not be trusted to implicitly, for I think it would be easy to show that there are cases where the danger and mischief would only be postponed for a time by such contrivance, and would reappear and act with full force when by irregular pressure on a bad and shifting sub-soil the concrete becomes cracked and crushed long before the time comes when the building would begin to fail by reason of age and general wear.

I assume as entirely beyond discussion that in the exercise of his profession the architect desires to do justice on the one hand to his own inventive genius, skill and reputation, on the other to the highest interests of his client. I have endeavoured to show that in order to do this he must learn and be to some extent familiar with the principles and applications of the science of geology as now understood. He must from time to time call in the aid of this knowledge to decide matters of vital importance, and he cannot do so properly without making them a subject of serious and special study. I have not entered into details, as they could hardly be fitly discussed in this place, but I have endeavoured to illustrate and explain certain general principles to which I think your attention as architects should be directed.

Since this memoir was in type, I have obtained from my friend Dr. Letheby the pamphlet by Dr. Pettenkofer, already alluded to, in which attention is drawn to the great influence of subsoil and rock on certain diseases, especially cholera and typhus. Dr. Pettenkofer points out that in the case of Gibraltar and Malta it was proved by British statistical returns that at a time when cholera was raging over a large area, there were certain small localities that escaped. On investigation it was found that, whereas the subsoil to a great depth, and in the case of Malta, the rock also was eminently porous and permeable, the spots that escaped were situated on impermeable clays.

There can, indeed, be no doubt that the health of a town site is greatly influenced by the condition of the rock and soil on which it is built, and that generally a moderately porous soil, admitting of the removal of moisture by drainage, is conducive to health, especially in a damp and comparatively cold climate, like that of England, and also that with us gravel and limestone as subsoil and rock are healthy as well as pleasant. But it is equally certain that where the underlying rock is deep and permeable, admitting of a considerable alteration of level of that surface of permanent wetness which is sure to exist at some depth or other under such circumstances, but which varies with the season, the result may be different, and it may require both knowledge and judgment to decide as to the relative value of sites, even with regard to water only. It is also true that wherever there is a great collection of human beings living over a permeable soil and rock, the effect of the accumulation of refuse and sewage cannot but be felt in the course of time. The water percolating from the surface will carry down organic matter, and this in time will inevitably make itself felt by generating unhealthy and miasmatic vapours occasionally reaching the surface.

But there is another question to be considered, which in warm and dry climates rises into great importance, and with regard to which the observations of Dr. Pettenkofer are very suggestive. All rocks are capable of absorbing, and therefore usually contain, a certain quantity of atmospheric air, either in its normal state or replaced by other gases. No doubt a certain change in the constitution of the gases absorbed may take place, in consequence of an action well known to occur in porous and spongy solids when mixed gases pass through them. The quantity of air or gases contained in all

rocks must vary, and must be affected by changes of weather. During dry and hot weather large quantities are given off, and during colder weather re-absorbed. In rocks then that contain much air, either in consequence of their great absorbent power or their mass, whenever there has been received into the body of the rock by percolation from above any quantity of organic matter, and this organic matter has become decomposed, the gases given off during hot summer days are liable to become dangerous miasma, and when cholera and fever are prevalent are especially liable to communicate infection. I cannot but attribute to this cause the extremely bad sanitary state of some districts in the Mediterranean—healthy enough so long as there is rain, but poisonous in the dry autumn; and in these cases I can easily understand that the intervention of even a small and thin band of clay may be a source of safety, and the more so the nearer it is to the surface.

I need offer no apology for pointing out these facts and inferences in a memoir on building sites, and of which the application of geology to architecture is the professed subject. Sanitary considerations connected with and arising out of topographical and geological positions can never be dissociated from the practice of architecture, and I am sure you will agree with me that all knowledge that can help to a conclusion in such matters is not only desirable, but ought to be considered indispensable to the architect.

The PRESIDENT.—I am very glad indeed to find that the improved state of the weather, as compared with what it was on the evening when Professor Ansted's paper was first appointed to be read, has led to an attendance to-night more worthy of the important subject that has been brought before us, and more worthy of the author's high reputation. We are indebted to him for a paper so full of information and of matter calling for thought and study, that before I venture to ask gentlemen to give us the benefit of their remarks, I think it due to offer in the name of the Institute our best thanks to Professor Ansted for his kindness in preparing the paper, and still more for the courteous manner in which he postponed its delivery until a more favourable opportunity.

Dr. HENRY LETHEBY (responding to the President's invitation) said—The remarks made by the learned professor were most interesting, not merely on account of the relation of geology to architecture proper, but also because of its connection with sanitary science; for surely it was a matter of great importance, while considering the questions of site and durability of a structure, to pay some attention to the future well being of those who were to occupy it. I think, indeed, that in a sanitary point of view too much consideration could not be bestowed upon the application of geology to the whole circumstances of the case, as for example, to the ground upon which a building is erected and also to the materials of which it is to be constructed; for every medical man of large sanitary experience must have been constantly brought into relation with very expressive facts, showing how terribly the question of the character of the soil, and the nature of the materials of buildings, have been neglected. The views to which Professor Ansted has directed our attention this evening, are, I think, especially worthy of the consideration of architects, because they show how intimately the geological features of a soil are related to many endemic diseases, and to most epidemics. This has been especially observed by Professor Pettenkofer in his examinations of the various outbursts of cholera in different places; and his views were singularly confirmed by the facts which presented themselves during the last epidemic of cholera in London. It happened, indeed, during the epidemic of 1866, that certain places in the eastern parts of the metropolis were entirely exempted from cholera, while neighbouring places were seriously affected by it; and when the whole of the facts were enquired into, it was found, most remarkably, that the character of the soil was essentially different in the two places, showing that it had much to do, on the one hand, with the prevalence of the disease, and on the other, with immunity from it. In the City of London Union Workhouse, in the Bow Road, for example, where the force of the

epidemic was most severely felt, and where in the course of three or four days there were no fewer than twenty-six cases of cholera in one set of rooms only, namely the infirmary. In fact, during the interval from the 26th of July to the 4th or 5th of August, there were nearly fifty cases of cholera, and with one exception they occurred in that set of rooms only. This was a remarkable fact, and when it came to be enquired into, it was found, from an examination of the geological map of the district, that this infirmary of the workhouse in which the cholera cases occurred stood upon gravel, while the whole of the other portions of the building were erected upon brick earth or clay. [Professor DONALDSON.—Was that on the ground floor?] I do not know about that exactly, as the infirmary is a detached building, with three floors accommodating 179 patients. Another case, to which I would refer, is equally instructive, for it shows how the geological character of the soil may effect cases of this description. In a pauper school, at Limehouse, with about 400 children, situated in the very midst of cholera that was raging about it right and left, even in the same street, there was not a single case of the disease. When the circumstances of that case were inquired into by Mr. Whittaker, of the Geological Survey of England, at the instance of the Medical Officer of the Privy Council, he ascertained that the school building stood upon a thick bed or island of brick earth, and not upon gravel as was supposed; while the neighbouring houses, in which cholera had been so severe, were built upon made earth and gravel. There are many such instances quoted by Professor Pettenkofer, and which might be mentioned if time permitted: possibly, indeed, the immunity from cholera at Wanstead, Walthamstow, Buckhurst Hill, Leytonstone, Stamford Hill, and North Woolwich, may have been due to this very same circumstance; but, on the other hand, though clay may be to a large extent a protection during a visitation of cholera, it is in other respects a most unhealthy kind of soil for a permanent residence; for it is provocative of rheumatism, phthisis and other diseases, produced by a damp atmosphere. It would seem, therefore, that the immunity of a population from cholera, typhoid fever and endemic bowel complaints is dependent on the freedom of the soil from excremental soakage, and from variations in the level of the subsoil water. As regards phthisis, it is now abundantly proved that dampness of soil is an important cause of the disease, and that when works of drainage are carried out in any town, the mortality from phthisis notably diminishes. The investigations of Dr. Buchanan, on behalf of the Privy Council, have shown that in some of our large towns where subsoil drainage has been thus carried out the mortality from phthisis has sometimes diminished in a few years from 40 to 60 per cent. In the fifteen large towns which have been the subjects of especial enquiry, the average death-rate from phthisis has fallen to the extent of about 30 per cent. At Salisbury, for example, it has declined to the extent of 49 per cent. of the old mortality from phthisis; at Ely 47 per cent., at Rugby 43 per cent., at Banbury 41 per cent., and so on going down to 10 or 11 per cent. These are points which, although not strictly pertaining to the subject of architecture, may nevertheless command the attention of architects; for they show that the quality of a soil, and especially the geological character of it, is intimately concerned with the sanitary well being of those whose buildings are erected upon it. The same might be said of the influence of soil on the quality of the water, which is used for domestic purposes; but this is a large subject which I cannot venture to deal with on the present occasion, although it is intimately connected with the subject of the learned Professor's remarks; and I do no more than say that the nature of the emanations from the soil, as well as the quality of water derived from it, are subjects of the highest importance to the community, and therefore of interest to the architect. Lastly, the character of the stone of which a building is constructed is not without its influence in the sanitary condition of a building. This is especially so in the case of public hospitals, where the porosity or non-porosity of the stone of the inner walls may actually determine the question of healthiness or otherwise; for a porous stone will so absorb organic effluvium, that it may at last be

the means of diffusing septic persons to such an extent as to render the wards uninhabitable. In such cases there is no remedy, but the clearing of it out, and the thorough cleansing and disinfecting of the surface walls. All this would, I think, be prevented to a large extent by a careful consideration of the geological and physical qualities of the materials with which architects and builders have to deal; and this is especially needful in the case of hospitals and infirmaries, which require a stone of an impervious character. I make these few observations for the purpose of showing that however important it may be, on account of the building itself, for the architect to study and apply the principles of geological science, it is equally important, in its relation to the sanitary well being of those who will occupy that building.

Dr. DRUITT (also responding to the President's invitation) said—I have availed myself of the kind invitation given to me to attend here this evening, but without the smallest intention to address the meeting. I came to learn, and not to speak; but as the President has done me the honour to call upon me, I will venture to make one or two observations in continuation of those offered by Dr. Letheby. I would say in the first place, I think my friend who preceded me is a little hard upon architects, when he suggests that they have not hitherto paid sufficient attention to the geological features of sites of buildings, and the materials of which they are constructed. When human beings employ physicians they expect us to cure the disease, though they will not help us by giving up one error in their mode of living. In like manner, we expect architects to build healthy houses, although their clients prescribe not only the site, but the materials, the aspect, and every other circumstance connected with it. The lesson one learns, is what an exceedingly complex matter human life is, and how much it is affected by circumstances, whose influence no one dreamt of before. My friend Dr. Letheby may seem to some of us to have uttered a kind of paradox, when comparing Pettenkofer's researches with Dr. Buchanan's. In the first place, he pointed to the danger of too dry, too porous a foundation, and in the next place to the danger of too wet a foundation; and shewed that in our endeavours to avoid phthisis we come in the way of incurring typhoid and cholera. Now, though somewhat puzzling, these statements are no doubt each perfectly true and consistent. Professor Pettenkofer promulgated the theory that the prevalence of cholera and typhoid was coincident with a *low* level of water in the subsoil. It has been shewn by an American physician, and by Dr. Buchanan, that a prevalence of phthisis coincides with a high level of subsoil water. If we look at a town situated on a porous soil, we find multitudes of human beings contaminating the soil with those pollutions which are soaked up by the ground and usually carried away by the water which percolates the gravelly soil on its way to the nearest river; but when dry weather comes, then it is that what Dr. Letheby says happens—the soil becomes a medium of giving off the most dangerous miasmas, and the soil of the locality being foul and half dry, assumes the condition of an aguish country, which, if not thoroughly drained, had better be left wet than half dry. One is delighted to assist at a meeting like this, in which gentlemen like yourselves engaged in one important function relating to human life, in providing buildings to insure protection from the weather, and the enjoyment of civilized society, are seeking for their profession a true scientific basis. With regard to geology, I have nothing to remark, but if it is within the scope of the meeting, I would call attention to the practice of erecting dwellings on what is called "made ground." It is a very remarkable circumstance that on what used to be the fields round London, where notices were exhibited that rubbish might be shot, and the scrapings of roads, and all other offensive materials were deposited for a series of years, there has now arisen a city of palaces. If there is any truth in the statement, that emanations from the soil have an injurious effect upon the health of the people living in the houses placed in such situations, it is difficult to conceive that they can dwell in houses on such sites without deteriorated health. We have now

before us the puzzling phenomenon of the great increase of scarlet fever, and other disorders which appear to defeat all our efforts for their suppression. Probably the condition of the soil below the foundations of the houses may be one element in the matter. If there be truth in the views of those who hold that water is the great vehicle of cholera and other disease, there can be no question that when water containing impurities is allowed to soak into the soil and is retained there, it will give off emanations highly detrimental to health. Whether taken as a drink, or inhaled as vapour, poisonous water is probably at the bottom of a large number of diseases.

Professor DONALDSON.—Our friend Professor Ansted has created an additional claim upon our gratitude by the admirable paper he has read to us to-night. It is interesting, and the subject of course is of great importance. We know if we refer to old Vitruvius, that he has devoted the fourth chapter of his first book on architecture to the choice of site, and throughout his work we find allusions to the importance of careful consideration being given to the selection both of site and of water sources. I could wish that each young student possessed a copy of Vitruvius, and would read it through, for in it would be found not only illustrations of the canons of the ancients in regard to art, but practical lessons as to materials and construction, which are of the utmost value even in the present day. His was a comprehensive and judicious mind; and I am sorry that he is less valued than he deserves to be. I was going to say that the geological subject is one which has occupied our attention from the earliest days of this society, because on its first formation a series of twelve lectures were given by Dr. Dickson on the subject of geology, and now by the genius and experience of Professor Ansted it is revived, and we are called upon again still more and more to attend to it. The subject has two divisions—first, the selection of the site; and next, the application of the materials. In regard to the sub-foundations of houses, there are natural sub-strata and artificial sub-strata. With respect to artificial sub-strata there are circumstances alluded to by the last and the previous speaker, two eminent men—professional men—well known to the public from their reports on the subject, which are highly esteemed, and convey a great deal of information. As to artificial circumstances, we have throughout the country illustrations of their effects. There are the coal fields; producing large cavities below the surface of the earth, and underlying buildings, than which nothing can be more unsound. We find that in Glasgow itself whole districts sinking down, owing to the cavities produced by the abstraction of coal and iron. The same danger may arise in the excavations for stone, as in Paris, where numbers of buildings in the immediate vicinity have fallen down in consequence of the quarries underground, and we have in Rome, as you well know, in the catacombs, various instances in which it is necessary to attend to the substratum, to see whether it is sound naturally or artificially, and to ascertain whether there is cause to doubt the sufficiency of the substratum to support the buildings which would come upon it. We have a notable instance of this in St. Peter's at Rome. That edifice was built upon the ancient site of the Circus of Nero, and two bell towers were built on the front, which were obliged to be taken down from the insecurity of the foundation, there having been old constructions beneath. In the case of London artificial substrata arise from a variety of circumstances. There was, for instance, the old Walbrook. Many have been the casualties to the foundations of buildings in the bed of the old brook. Nothing could be more unreliable than building on such soil as that; and many of us here recollect the Fleet ditch lying an open stream northwards of Holborn, and since covered. The memory of the circumstances passes away. Architects build, not knowing the facts, on what they think is a good sub-stratum; but below it is treacherous, and serious consequences ensue. In Egypt there are whole towns built in series one upon another. I have seen a hill cut through, and there were laid bare the strata of villages of different epochs one upon the other. Occasionally the Nile overflows, sweeps over the mound,

and reduces the mud-built houses to mud again. Then came another generation of occupants, who built their houses on the same mound. You find tombs, and sepulchres, and mummy cases of different successions of ages, of the successive inhabitants. Therefore it requires great care to be fully aware of the previous circumstances that have prevailed in certain localities. We have had some useful references made with respect to the unwholesomeness of houses. A most remarkable circumstance which has always struck me in looking over the returns of the Registrar-General is the sanitary state of Birmingham—a large town, with houses closely packed, a large population, and various manufactures carried on, some of them not of a very healthy nature. And yet we have the marvellous fact that the death scale in Birmingham is lower than that of any other town in England. The opposite is the case with regard to Glasgow, with a low soil, a low class of occupants, and imperfect sewerage. With respect to the Bow Road case mentioned by Dr. Letheby, it was certainly a very remarkable one. I should have thought myself that a sub-stratum of that kind would have conduced to the health of the occupants, being partly on a gravel soil and partly on old brick rubbish. We have hitherto always considered that a permeable soil, which will carry away the surface water, was rather healthy than unhealthy; and that a compact soil, like clay, would retain the impurities that were carried into it. Therefore one can hardly find a solution of what appears to be an anomaly. It is to be observed that drainage not only carries off the surface water, but enables the soil of a city to be carried off and pass away from being stagnant in the city. I think myself the great advantage of draining is the carrying away of the soil, and not merely the surface water. We must always regard as a great principle that the rivers are the great sewers of the country, and not that drinking water is to be supplied by the rivers, because towns and villages on the banks discharge all their ordure into the rivers. It is, however, a remarkable circumstance, that, after the stream has flowed on for a certain distance, the water resumes its purity, whether from the deposit of its foreign matters on its bed, or from their evaporation into the air. At the same time I may say the rivers should be considered as the great sewers of the country through which they pass; and the potable water should be derived from springs and fountain sources or deep wells, and that these are the only reliable supplies for pure water. In London we are relying on the north and central portions upon the New River; to the west and south upon the Thames for our domestic water supply. The one is pure, the other mixed with all sorts of impurities. Such is the theory, which I venture to submit, in regard to rivers and springs. With respect to the absorbent stones alluded to in Hospitals, not only is the stone but the very paperhanging is an absorbent material; but these absorbent stones may be remedied by a coating of Kean's or a like cement, which have a non-absorbent property. These are the practical suggestions which occur to me upon our friend's paper and the remarks of previous speakers. I beg to conclude by proposing a cordial vote of thanks to him for his kindness in favouring the Institute with this commuication. Our friend has mentioned the Holborn Viaduct. I do not think that there is any fault in the foundation. The defect is either in the material used, or in the mode in which the joints are set. That I believe to be the cause, and not the effect of the subsoil of the Holborn Viaduct.

Mr. Wm. Haywood, Fellow, said—I should not have risen to-night, for I have nothing to observe beyond a general concurrence in the views expressed by Professor Ansted, had you, Sir, not called upon me; and I do not know that I have anything to say unless it is with reference to the columns of the Holborn Viaduct; and as I have had to say a great deal upon that during the last year and a half, I am getting tired of it, and I am afraid this Institute must be tired of it also. I should not have risen, because I did not clearly understand what the Professor meant by his allusion to the subject. I do not know whether the rules of this Institute enable members to ask questions of gentlemen who read papers;

but if I am permitted to ask a question, it would be whether the Professor is of opinion that the fractures in those columns were attributable to the foundations. If he is not I will sit down: if he is I will say a few words upon it. May I ask what Professor Ansted meant by the allusion he made?

Professor ANSTED.—My impression was that the foundation had to a certain extent given way.

Mr. HAYWOOD.—I am happy to have had the explanation, because I could scarcely imagine that a man of the eminence of the Professor would have been content with a mere allusion to the subject. It was in his mind that the foundation had something to do with it, and that is a practical point; and as there is nothing more instructive than an account of a failure when truthfully given, and though for reasons which I need not state here, I cannot enter closely into the cause of the fracture of the columns—though undoubtedly it will hereafter be discussed either in this Institute or before another body, to which most members of this Institnte have access—still, as regards the foundation, I am quite prepared to tell the meeting all about it. The Fleet River was at that spot, perhaps from 100 to 150 feet wide. In the course of time it became the Fleet Sewer. The bottom of the old Fleet River was something like twenty feet below the old level of the street. The tide rushes up the Fleet Sewer and fills it about two-thirds of its height. The height of the sewer is 13 feet, the bed of the sewer and the bed of the old Fleet River being about the same level, has from 10 to 12 feet of water on it twice in every 24 hours. The bed of the old Fleet River was in clay, and the bed of the sewer is in clay. The foundations of the Holborn Viaduct at that spot were put in bit by bit, without a coffer-dam, with the Fleet Sewer between them, subject to the *enormous* scouring action which results from the drainage of so many miles of country, and to the tidal action; therefore, as you may suppose, the foundation was put in under great difficulties and very much anxiety, and they were carried to something like 7 and in places 8 feet below the level of the old Fleet River, and is solidly embedded in a compact mass of the London blue clay. I believe if you take the bearing area of the concrete base on which the granite pillars stand, it will bear per square foot of surface 5, 6, or 7 times as much as it can possibly have to bear supposing the bridge to be packed with human beings; and when a close examination was made by myself, and perfectly independently of me by three engineers not selected by myself, they found as closely as it is possible to ascertain anything of the sort, that the foundation had not yielded in the slightest degree. And now all I have further to say is, that those three engineers made their report, attributing the fracture to bad jointing, and I think any man who will take the trouble to go and look at this somewhat instructive partial failure, will be of opinion that the defect in the columns is attributable entirely to the bad jointing. Now, although I do not admit defect, if there was a defect in the design at all, it was that I endeavoured to make too fine a joint, and expected as conscientious workmanship as if I had worked the stone myself. I did not get it, and a space of the thickness of a sixpence between the surfaces in such an inelastic material as granite, would be as likely to be the cause of fracture as if it were a much greater space. When the columns cracked they found their bearing, and they have never moved from that time to this. That is all I now can say; but if any enquiries are made of me as to the nature of foundations which it may be pleasing to the Institute to have information upon, I shall be happy to answer them.

Professor ANSTED (in reply upon the discussion) said—If it had not been that it has brought out so admirable an account of the history of the foundation of the Holborn Valley Viaduct, I would offer my apologies to the meeting for having introduced what I believed to be an illustration of one of the points alluded to in the early part of my communication. I thought it likely to be so, knowing, as I do, the general state of the Valley of the Thames, and the extreme irregularity of bottom in most parts, and the fact that where small streams feed a larger stream, there is often a double accumulation of

alluvial matter, the one placed transversely upon the other, and in that way forming a deposit likely to be as bad for foundations as any thing can well be. From the account which Mr. Haywood has given of having reached the London blue clay, it is clear that the view I entertained was incorrect, and therefore I at once withdraw my remarks with respect to the Holborn Viaduct foundation. At the same time I would take the opportunity of reminding the meeting that a bed of clay reached under such circumstances in preparing foundations for a large construction might, though apparently thick and steady, have had below it another mass of alluvial matter and loose sand. I have myself seen such cases where loose and quick sands have underlain 40, 60, and even 90 feet of thick sound clay. Similar cases are not even uncommon in river valleys, and I regret I did not quote some instance more distinctly to the point, and one in which I had the facts more completely before me. I hope, however, that Mr. Haywood will not think I had the slightest intention of throwing blame upon him. I was aware, from the reports of the engineers appointed to examine the work, that so far as he was concerned he was held perfectly blameless. And now, turning to another subject, I would say that I cannot enter with my friend Professor Donaldson into the great water question; but if I could, I should have a great deal to say on that subject, and I should by no means agree with the opinion he has expressed as to the advantages of well water and river water for drinking purposes. I pass that subject by, tempting as it is. There is, however, another point alluded to by Professor Donaldson, which calls for a word or two from me: that is with reference to the case in which a permeable rock is supposed to carry away the moisture which falls upon or runs over it. Whatever may be the contents of the water that passes over or comes in contact with such permeable rocks there will be no harm done if the whole can escape by natural or artificial deep drainage, but if the impermeable rock below is basin-shaped, the sewage matter that is carried down with the water is collected there, and may prove very mischievous. When the impermeable rock is clay, and the hollows on the surface are filled up with clay, the worst instances of miasma are I believe likely to arise. I do not know that there are any other points on which I need detain you. I had not forgotten our ancient friend Vitruvius, and indeed Professor Donaldson was kind enough to tell me that I should gain some information from him; however, I am bound to say that I have not found much in the way of geological information that I could render available, or I should certainly have felt it necessary to grace my memoir with a Latin quotation.

The PRESIDENT.—I must not forget that the vote of thanks proposed by Professor Donaldson has not been formally seconded.

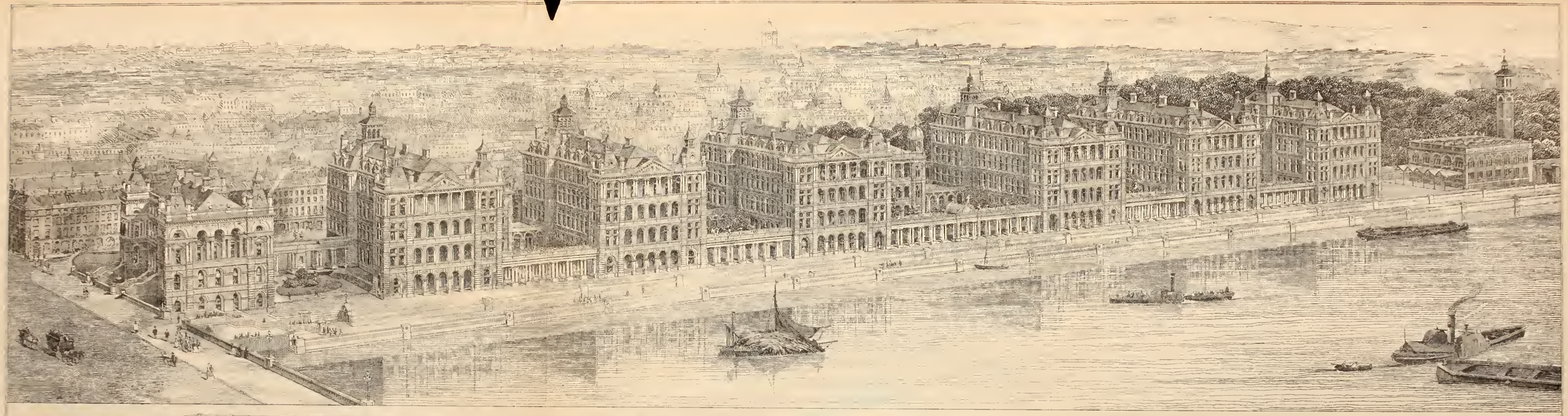
Mr. PHÈNÉ SPIERS, Associate.—I have great pleasure in seconding the motion, and in so doing would call attention to one of the main points of the lecture, which has not been yet referred to by any of the speakers. Professor Ansted has told us of the desirability of establishing some systematic course of instruction to be given to architects in the particular science of which he is a Professor. I hope I shall not be guilty of indiscretion when I say that some ten months ago the learned Professor was asked to assist the art classes we have since formed in connection with the Architectural Museum, and kindly offered to give a course of lectures on geology. The matter has been lost sight of, and I have only been waiting for an opportunity to bring it forward. I may say that similar courses of lectures have been given by the Architectural Association, and they have been attended with complete success. I know of no subject on which lectures can be given with more advantage to the body of students down stairs than on geology; and I hope an opportunity will be taken by the Council to establish some system by which such lectures may be given.

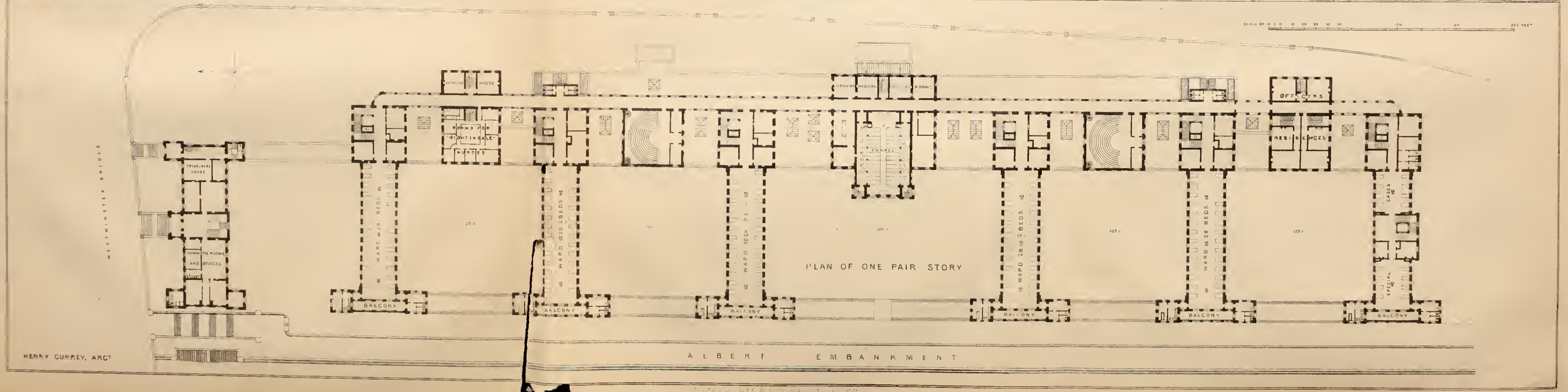
Mr. BENJAMIN FERREY.—I rise for the brief but pleasant purpose of supporting the vote of thanks which has been proposed to Professor Ansted for his able and learned paper, and also to Dr. Letheby

and Dr. Druitt for their remarks, which have been so instructive to us. We are deeply indebted to those gentlemen for the information they have given us, which I hope we shall all be able to apply in our respective practices.

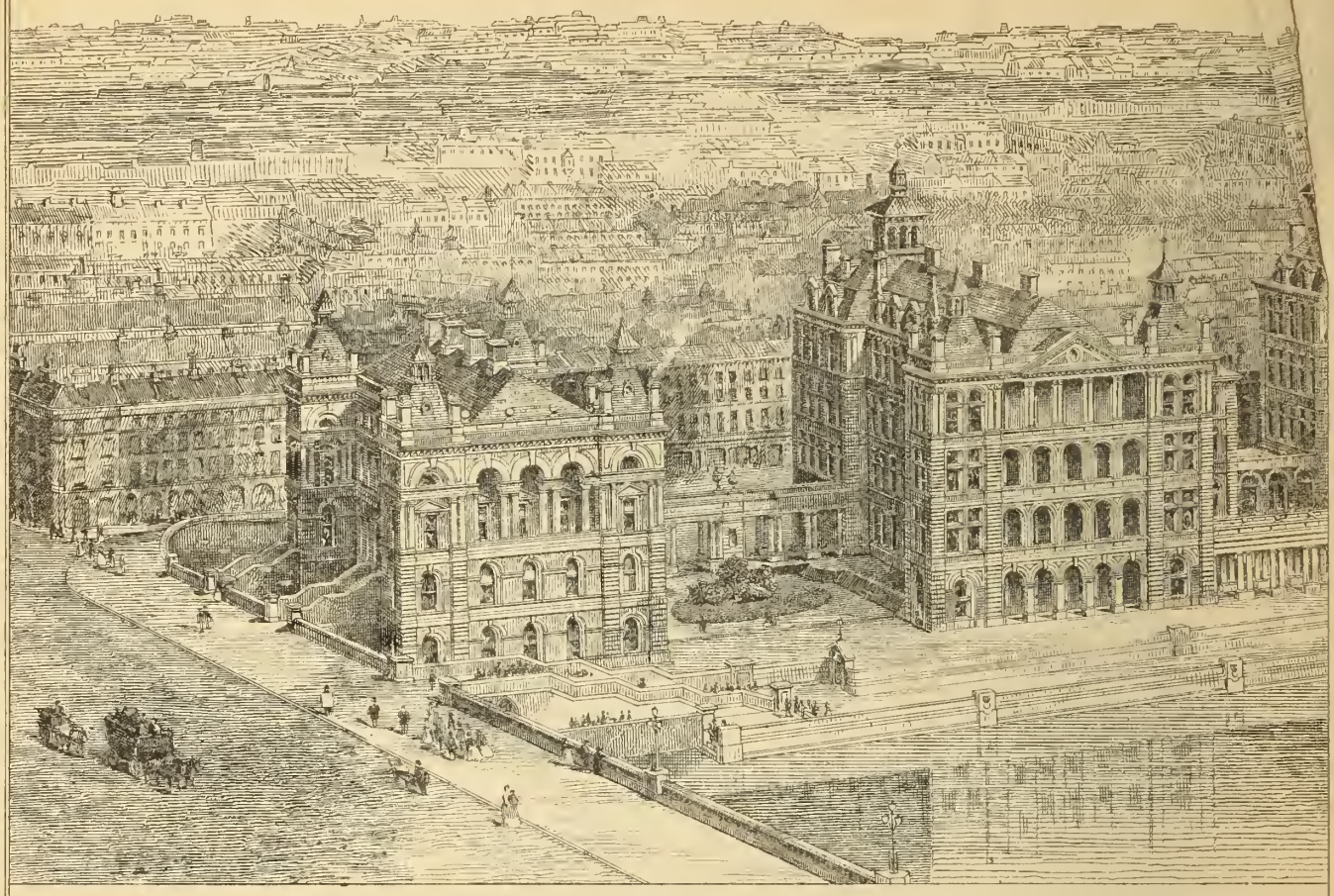
The PRESIDENT then put the resolution, and remarked: Of all the papers I have heard, this has been one of the most interesting to me. If I have any other large building to construct, I shall not trust to my own little knowledge of geology, but I shall ask Professor Ansted, or some one as deeply versed in the subject as he is, to advise me.

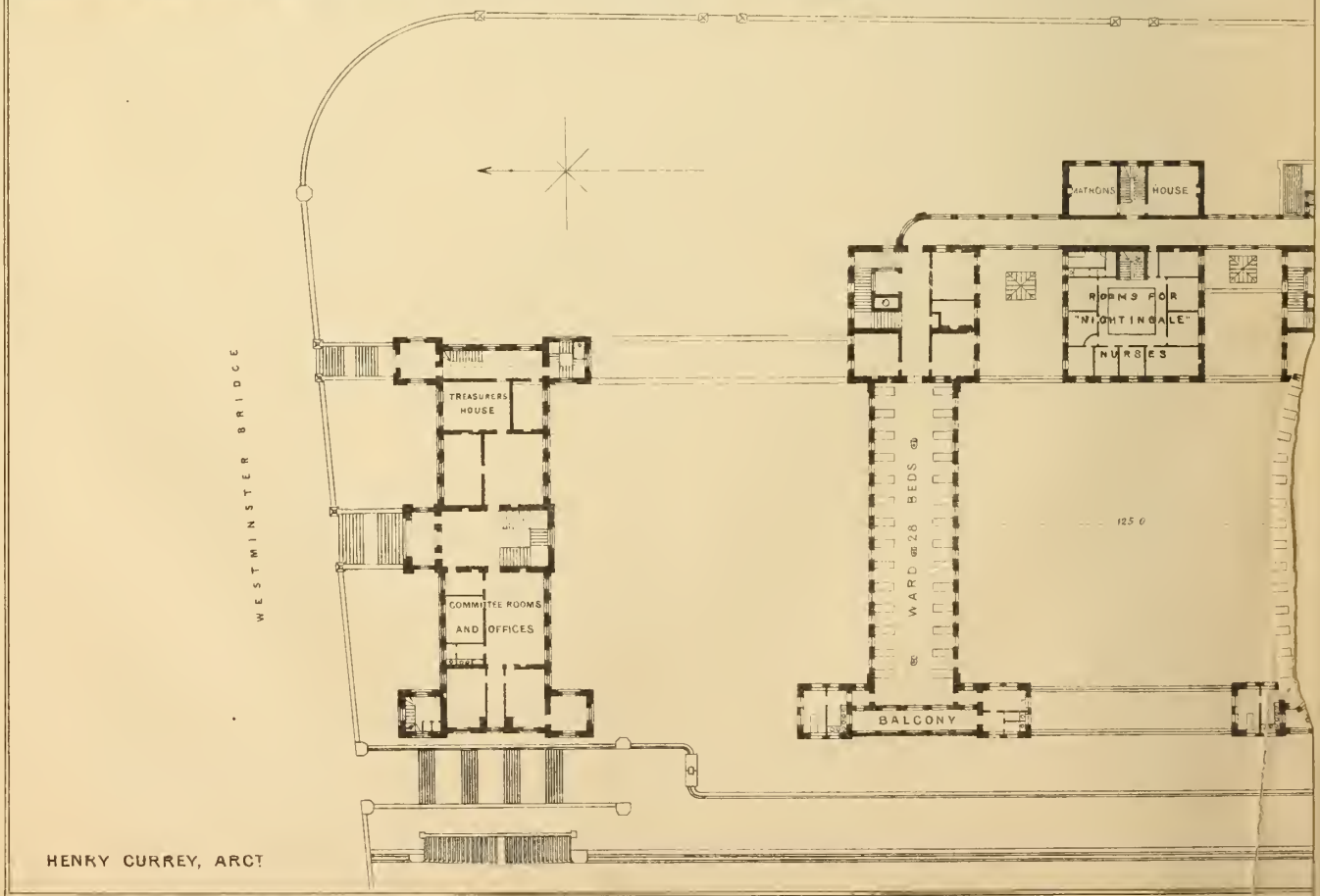
The Meeting then adjourned.





VIEW OF ST THOMAS'S HOSPITAL, LONDON.





HENRY CURREY, ARCT

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, 23rd January, 1871, the following Paper was read—THOS. H. WYATT, President, in the Chair:—

ST. THOMAS'S HOSPITAL, LONDON.

By H. CURREY, Fellow.

IN compliance with the request of your Committee, I have much pleasure in laying before you a brief account of the new St. Thomas's Hospital, now approaching completion on the Albert Embankment, at Lambeth. The hospital at Southwark, which had existed in some shape since the year 1207, was incorporated and received its Charter from King Edward the Sixth in the year 1551, and a few preliminary remarks on the cause of its migration from that ancient site may not be uninteresting, particularly as such removal involved many important questions, not perhaps purely architectural, but such as are continually arising in our professional practice.

In 1859 a certain adventurous railway company, called the Charing Cross Railway, conceived the idea of taking a line from London Bridge to Charing Cross, and their great difficulty appeared to be to pass the Borough without intrenching either upon St. Saviour's Church or St. Thomas's Hospital. They, however, respected the Church, not perhaps from any religious sentiments, and determined, as being most likely to succeed in their application to Parliament, on taking a small corner of the grounds of St. Thomas's Hospital, and they accordingly served a notice of such intention on the authorities. The Governors, feeling that a railway perched upon an iron viaduct within ten or twelve feet of a most important portion of their hospital, irrespective of the damaging effect it would have on the whole institution, would be destructive of its usefulness, were reluctantly compelled to oppose the bill in Parliament. After a long and arduous struggle, the Committee of both Houses came to the conclusion that there was a great public necessity for such a communication, and that the hospital must yield, and the Lords' Committee, after expressing a strong feeling on the injury which would accrue to the hospital, passed the preamble. Certain negotiations followed, but came to no result. In December, 1860, the railway company served a notice on the hospital to take the part they required. The Governors felt that a railway and a hospital could not co-exist in such close proximity, and after full consideration, gave the company notice to take the whole under the 92nd clause of the Land Clauses Consolidation Act. The company resisted such request, but on the matter being argued before the then Vice-Chancellor Wood, he, without hesitation, determined that the hospital view was the correct one, and that the company could not escape from the obligation of purchasing the whole hospital. Such being the result, one cannot but regret that the line was not taken directly across the hospital, passing through the centre of the London Bridge station, thus accommodating both the Brighton and the South Eastern lines, and crossing the High Street at a right angle instead of the tortuous and inconvenient plan which has been carried into execution at an enormous cost. Next came the question of how the compensation was to be assessed, whether by jury or by arbitration, and looking to the uncertainty which then attended the verdict of juries, it was determined to refer the matter to arbitration, and after considerable difficulty in finding a suitable umpire acceptable to both parties, Mr. John Stewart, of Liverpool, a gentleman of great eminence in such matters, was ultimately appointed in September, 1861. The

reference commenced and lasted for seven days. There was necessarily a considerable discrepancy in the valuations made on behalf of the hospital and of the railway company, the highest, on behalf of the hospital, being £ 478,000., and the lowest, on behalf of the company, £ 145,000. Mr. Stewart's award amounted to £ 296,000.

In 1862 the company took possession of the hospital premises, arrangements having been made by the governors for the use of the Surrey Gardens as a temporary hospital. A fire had recently occurred, burning out the whole of the interior of the music-hall, and by the introduction of new floors and roof, and sundry alterations to outbuildings, a temporary hospital was provided for about 200 beds in a very short time, and has, I think, fairly answered its purpose during the interregnum. Next came the difficult question of the selection of a site for the new hospital. The Governors had no compulsory powers of purchase, and to acquire eight or ten acres within reach of the population was a matter not easy of solution, and the question was further involved by the views expressed by certain persons as to the desirability of making it a suburban hospital. Several sites were suggested and valuations made, one being the removal of Bethlehem to the country and the occupation of that site for the purpose of St. Thomas's Hospital, and I prepared a design and estimate for a new Bethlehem Hospital to be erected at the cost of St. Thomas's. All this, however, dropped through, and ultimately the surplus land created by the Albert Embankment was fixed upon, and a contract made with the Metropolitan Board of Works for about eight and a half acres when embanked at the sum of £ 90,000, half of the eight and a half acres being land reclaimed from the river. Great objections were raised by some parties to the site: it has been called a mud-bank, and all sorts of uncomplimentary names, but it appears to me that a better site for a metropolitan hospital could not have been selected (always of course presuming the river to be cleared of the sewage). The great tidal flow of the river forms a powerful natural ventilator, changing the volume of air continually, and the quiet soothing influence of water, and absence from noise and dust, renders it in my opinion a most desirable locality for the purpose of a metropolitan hospital. I do not mean to imply that some breezy down in the country would not be more conducive to health, but to place a metropolitan hospital in any such distant locality would render it practically useless.

Having sold the old site, and done the best we could for the patients by the conversion of the Hall at the Surrey Gardens (which has seen the strange vicissitudes of an abode for music, a tabernacle for Mr. Spurgeon, and a refuge for a hospital), and the question of a new site being settled, I was instructed to prepare the necessary design, and as the subject of competition is one of some interest, I may mention, that on my appointment as architect and surveyor to the hospital, now some twenty-five years ago, the Governors reserved to themselves the right of submitting any great work which might arise to competition. They did not, however, avail themselves of this right, and although it is not for me to say anything as to the result of the course they took, yet I venture to think that they were relieved from some trouble, anxiety and expense, and I take this opportunity of thanking them for the confidence they reposed in me. A Committee of Governors, accompanied by myself, visited several of the Continental hospitals, and the Committee of the Medical Staff assisted in maturing the several matters of detail. The design is arranged on the Pavilion system, now generally admitted to be the best for hospital purposes, and specially suitable for the land on which the hospital was to be erected. The nature of the site did not admit of the pavilions being placed on both sides of a central court or corridor, as at the great French hospital at Lariboisière, the hospital at Brussels, or the Herbert hospital, but they all ranged on the river side of one continuous corridor, 900 feet in length. This arrangement has the disadvantage of increasing the length of communication from the several departments, but at the same time it renders the ventilation more free by diminishing the length of the courts. The prominent

defect of the Lariboisière hospital, viz. the too close proximity of the blocks with reference to their height, has, I hope, been avoided. The pavilions are placed at a distance of 125 feet from each other, (the centre court being increased to 200 feet), which distance, it was calculated, would admit of ample sunlight and air to every block, the axis of the wards being due east and west.

The general disposition of the building will be seen by reference to the plan of the one-pair story, on which the isolation of the blocks is more distinctly indicated, the intermediate spaces on the ground story being filled in with lower buildings, for purposes hereafter mentioned; and it was my endeavour to make the plan as simple as possible in its arrangements, for facility of inspection and working. Corridors run the whole length of the hospital on the ground and one-pair stories, and connect the several blocks of wards or pavilions. These corridors are lighted by large windows on both sides, and in the event of it being deemed necessary to isolate any particular block, it could be done by putting screens across the corridors, and removing the sashes from the adjacent windows. These corridors are not carried higher than the one-pair story, but the flat roof over forms a means of communication to the several blocks on the two-pair story. The pavilions are placed at right angles to the corridor, from which a passage leads direct to the wards, on one side of which is the staircase. The wards are designed to be 28 feet in width by 120 feet in length, and 15 feet high, and will accommodate twenty-eight beds, giving a cubic capacity for each patient of 1800 feet. The beds are placed at distances of 8 feet from centre to centre, and the windows are arranged alternately with the beds, at a level to enable the patients to see out. A cheerful aspect is given to the wards by the end lights communicating with the external balconies towards the river, where patients may be placed on couches or chairs in fine weather. Small wards for two beds, contiguous to, but not communicating with the general wards, are provided in each block for the reception of special cases, which it may be deemed desirable to separate from the other patients. Adjoining the passage are placed the sisters' room, the ward kitchen and a room for the medical officers' consultation. The staircases are wide and easy of ascent, the treads being $12\frac{1}{2}$ inches and the rise $5\frac{7}{8}$ inches. The well holes are occupied by the large lifts and ventilating shafts hereafter referred to. The water closets, lavatories and bath rooms attached to each ward are projected from the main building, and are cut off from the ward by intercepting lobbies, with windows on both sides. The water closets, lavatories, &c. have also windows on all four sides, to provide a thorough ventilation. In this department the foul linen and dust shoots are arranged, communicating with a receiving room in the basement for external removal. Dormitories are provided for the nurses and servants in the attic story, each having a separate sleeping compartment, care being taken to prevent the ascent of any ward atmosphere reaching thereto.

The main hospital may be said to commence on the first floor, and consists of three tiers of wards, there being four smaller wards provided on the ground floor for the reception of accidents, &c. The total amount of accommodation provided is about six hundred beds. The wards have flat ceilings throughout, and the windows are carried up to the ceiling, to ensure a thorough change of air in the upper part of the rooms. From the corridors on ground floor patients will be quietly and conveniently conveyed by lifts to the various wards (these lifts will be referred to presently); the corridors will also afford a place of exercise for the patients in wet weather, and the covered colonnades adjoining the river will form an agreeable lounge for patients approaching convalescence.

The above description applies generally to all the pavilions, except the southernmost, which is designed for special diseases, inadmissible to the general wards. The wards in this pavilion are smaller, and are arranged for males and females, being separated by a central staircase. The wards on the ground story correspond in general arrangement, but in consequence of the main corridor on ground story being placed next the internal courts, the wards are shortened to admit of the introduction of the necessary rooms in connection therewith.

The general entrance to the hospital is placed in the centre, and will be approached from the Palace New Road. The entrance hall is capacious, forming the sub-structure of the chapel, and its dimensions being large will be found convenient for the reception of the patients' friends at the times appointed for visiting. The steward's or superintendent's offices are placed immediately in front of the entrance hall, so that everything passing in and out of the hospital will be under his immediate supervision. From each side of the entrance hall branch off main corridors of communication connecting all the different departments. The ground floor of the first pavilion to the left is appropriated to the kitchen department, as being as nearly central as possible. It comprises kitchen, scullery, and cooks' rooms, with larder, bread room, &c., on the basement immediately under. A serving place is provided, where the patients' food will be distributed; it will then pass along the corridor to the different pavilions, and be conveyed up a small lift to the different wards. The ground floor of the first pavilion to the right is appropriated to the matron's department, with a commodious room for linen stores. On the right of the entrance hall is placed the principal staircase which leads direct to the corridor on the one-pair story, and will be used by visitors to patients, or for the general purposes of the hospital. It communicates directly with the resident medical officer's apartments, which are placed in the central block, consisting of sixteen rooms and a common room. Two operating theatres are provided (communicating with the corridors) lighted from the northern slope of the roof, and of ample dimensions to admit of a large attendance of pupils. A private room is attached to each theatre for the operator, with a second room in which a patient may be temporarily placed after an operation. Conveyance to the mortuary will be provided from the basement by an underground passage without exciting the patients or the public observation. The dispensary and surgery are placed conveniently for the service of the hospital into the main corridor, and of the out-patients (who are more particularly referred to hereafter), from the opposite side. The laboratory, drug and store rooms are placed in the basement story immediately under the dispensary.

All applicants for relief at the hospital will enter at the covered porch in Palace New Road, and will be received in one of the admission rooms according to sex; they will then be informed whether they are to be admitted into the hospital or to be treated as "casualty patients," or as "out-patients." If admitted, they will be passed through the hospital corridor to the wards. If "casually," they will pass to the respective waiting rooms for males or females, from thence into the male or female surgery. They will procure their appliances at a window immediately contiguous, and pass out at once. If the applicant is to be treated as an out-patient, he will be directed to the out-patient department, which is placed in the corresponding wing. The out-patients enter at a door towards the southern end of the hospital, and pass through a large waiting room, 110 by 37, in which they will be arranged and classified. The physicians' and surgeons' rooms are ranged parallel with this room. Having been seen by the physician or surgeon, the patients pass into a second room, where they will wait for medicine or appliances from the dispensary and surgery windows, and after receiving them, pass out into the Palace New Road, without entering the hospital corridor. A staircase leads direct from the out-patients' waiting room to the out-patients' baths, which are provided in the basement. Sufferers from accident arriving will be conveyed directly into the accident receiving room, and from thence, when the cases are serious, immediately through the hospital corridor to the wards, and cases of accident on or in the neighbourhood of the river may be brought to the hospital and received from the landing stairs.

The administrative offices are placed next Westminster Bridge, and be approached therefrom; they will comprise the governor's hall, committee rooms, almoner's room, counting house, receiver's room, strong room, waiting rooms, and offices for the clerk and surveyor of the hospital, the treasurer's residence, &c. A staircase will connect the treasurer's house with the main corridor of the hospital.

The two lower stories of this block will contain residences for porters. Four houses are provided for resident officers, containing eight rooms each, exclusive of domestic offices. They will be approached from the Palace New Road, and communicate in the rear with the main corridors of the hospital. For the last eight years, nurses selected by Miss Nightingale have been trained (the governors believe with great advantage to the public) in St. Thomas's Hospital; and in the design for the new hospital, provision has been made for an increased number. The training institution adjoins the matron's residence, and will afford accommodation for forty probationers, who will be trained to the hospital wards for the council of the Nightingale Fund. Each probationer is provided with a separate sleeping apartment, ranged round a central gallery, with all necessary bath rooms, &c., and a large day and dining room on the ground floor.

The chapel is placed in the centre of the building, communicating with the corridor, with convenient access for both sexes. The school buildings occupy the southern end of the site. They consist of a large museum, 85 by 30 and 34 feet high, with two galleries, a museum for chemistry and materia medica, medical, anatomical and chemical lecture theatres, library and microscope room, dissecting and post mortem rooms, chemical and pathological laboratories, &c., affording the medical student opportunities rarely, if ever, equalled in completeness. The extreme point is occupied by gardeners' sheds, stables, &c.

The new wall enclosing Lambeth Palace grounds was built at the expense of the hospital in exchange for certain pieces of land surrendered by the late Archbishop of Canterbury to improve the boundary of the hospital site.

The designs were completed in June, 1865, and were exhibited to the Governors and others interested in the subject at the London Bridge Hotel for some weeks, and were ultimately approved by the General Court of Governors and by the Court of Chancery, whose sanction under a special Act of Parliament it was necessary to obtain. In April, 1866, the contractor for the Embankment having made considerable progress with the river wall, and being about to commence filling in and levelling the site, I reported to the Governors that it would appear most desirable that the foundation of the hospital and the embankment works should proceed simultaneously, and thus avoid the great expense of excavating and removing the material which was about to be filled in, and save a considerable amount of time in preparing the foundations, while the necessary details and contract for the superstructure were being prepared. A contract was made with Mr. Webster for the foundation works, and he at once proceeded vigorously with the same on the foreshore, but great difficulty was experienced in obtaining possession of the several properties which fringed the bank. The building stands partly on land reclaimed from the river and partly on the shore. The foundations on the river portion are carried down to the London clay. Those on the shore stand on a sound bed of gravel, which overlays the London clay, the difference in level being obtained by wide steppings, as shown on the sections. The ends of the blocks next the river have a solid foundation of about 22 feet deep over the entire surface, forming a toe to the whole. The long flank walls of the pavilions have a foundation 10 feet in width, and the same depth, 22 feet, up to the old river wall. The concrete is then stepped up, and a platform of concrete, about 5 feet deep, is laid over the whole surface of the remaining portion of the building. The land or spring water stands at a level of about 4 feet above the clay. A drain was laid along the whole length of the hospital at the back of the river wall to a sump, and the excavations were all pumped dry before the concrete was put in. The whole of the concrete is composed of blue lias lime and clean Thames ballast up to a little above the land water line in proportion of six to one, all above that in the proportion of eight to one. The strata on the shore consisted of made ground, then gravel varying in compactness, resting on the London clay, which rises gradually up from the river. The

strata on the river portion consisted of loose and sandy gravel down to the clay. The Embankment wall is also carried well down into the clay. As regards the terrace wall which intervenes between the end of the hospital blocks and the Embankment wall there was no weight of superstructure to carry, but it was necessary to go down to the clay to get any thing like a bottom. To have carried the whole down would have been very costly. It was therefore determined to build it on piers and arches. These piers were carried down 5 feet square in concrete, six to one as before, and arches turned from pier to pier in Portland cement concrete, in the proportion of five to one, the ballast being fine and small. The arches were turned on boxed centres, which were shifted from time to time as the concrete hardened, and the ground filled in all round. Two or three of these arches were turned in Coignet's beton as an experiment, but the Portland cement concrete was found equally strong and cheaper. The foundation of certain portions of the low outbuildings at the extreme end of the ground are executed on the same principle on piers and concrete arches; I am glad to state that owing to the care with which the foundations generally were put in and the superstructure raised, I am unable to discover the slightest settlement over the whole area of the extensive building. Scarcely any relicts of antiquity were found in the excavations.

During the execution of the foundations the working drawings and specification for the superstructure were completed, and the bills of quantities were prepared by Messrs. Strudwick and Co. and Mr. Richard Roberts, and tenders were received on July the 18th, 1867, from fourteen of the most eminent builders, the amounts ranging from £382,000 to £332,748, which latter was submitted by Messrs. John Perry and Co. of Stratford, and which after full consideration was accepted. Had stone ashlaring been used instead of red bricks the additional cost would have been about £25,000, which the Governors did not feel justified in incurring, and which, personally, I see no reason to regret. The contract was settled in October, 1867, and the contractors commenced erecting stone sawing machinery, laying down tramways, and making other preliminary arrangements, and on the 13th of May, 1868, Her Most Gracious Majesty laid the first stone. The ceremony was conducted with much state in the presence of 3000 spectators in a pavilion erected specially for the occasion, and the arrangements appeared to give general satisfaction. The stone laid by the Queen forms the north-east angle of the substructure of the chapel, and stands above the ground-floor line at the foot of the public staircase.

I will now proceed to state a few details of the construction, the warming and ventilating arrangement, and the cost. The footings were built with what is technically known as No. 2 wire cut Galt bricks, and the specification provided that the walls generally were to be built with the very best stocks, but that the piers in the flank walls of wards were to be built with Galt bricks, for reasons which I will presently describe. Owing to the great difficulty in obtaining a satisfactory stock brick in such quantities as we required, the contractor found it to his advantage, considering the small amount of fracture and waste, to use Galt bricks, and the whole of the work is executed in that material. They make excellent good sound work, but unless the joints are left very rough on the edge they do not afford so good a key for plastering as ordinary stocks. The greater portion were supplied by the Burham Brick Company. Inverted arches are turned under all window openings above the footings, and the piers in flank walls of wards being reduced to a small area by the large window space desired, and having to bear on the ground story an accumulated weight of 110 tons, were carried up with the very best Galt bricks in Portland cement, with Portland stone bonders the whole size of piers, introduced at every four feet in height. Every alternate window in basement was omitted with a view to obtain a larger area of piers on that story. Hoop iron bond is introduced at the level of each floor where it runs continuously round the building without any necessity of severance. The area walls, 14 feet in height, were built as shown on plans and sections, with a view to resisting the great pressure of earth filled in at back,

and to preserve the facing from being disfigured by percolation, the base of the pockets being filled in with concrete. The building is faced with red bricks, and great pains were taken in ascertaining the best quality for the purpose, and none appeared equal in quality and colour to the Farcham brick. Negotiations were therefore entered into with Mr. Cawte, of Fareham, in Hampshire, who opened a new field adjoining his old works, and made special arrangements for supplying the quantity required. The bricks were put into vessels at his yard, and brought alongside at Westminster, thus avoiding the damage and breakage of railway transit and carting from station. They were made specially, and the size so arranged as to bond accurately with the Galt backing. The bricks are excellent both in colour and quality, and Mr. Cawte used every exertion to keep us supplied with material as the work progressed. The number of bricks consumed exclusive of the facing bricks has been about twenty-five millions. The stone used is for the most part brown Portland, from Messrs. Hollands, Waycroft and Maggott quarries. No. 17. Saw frames, besides hand saws, have been constantly at work sawing the material, and the capacity of these saws appear to have been the gauge of the progress of the structure. Steam moulding machinery and large rubbing beds have also been used to a considerable extent. The quantity of stone used has been about three hundred and seventy thousand cubic feet. The consoles under main cornice, the caps of columns, and pilasters, the balusters, and the vases and terminals on balustrading are executed in Ransome's concrete stone. The material appeared peculiarly fitted in the present case where there was necessarily a great repetition of the same model, and consequently a considerable economy. Had it not been for this useful material I should probably have had to be content with the long line of balustrading unbroken by any vase or terminal. The pedestals would have remained vacant as they do in many instances where designed for sculpture, but the sculpture never arrives. It harmonises well with the Portland stone, and although many of my professional brethren would hesitate to use any artificial material, I venture to think that such hesitation may be carried a little to excess. The floors and flat roofs are constructed with wrought iron girders and "Dennett" arching. The latter material, as you are well aware, is composed of broken bricks or stone and sulphate of lime, in the proportion of three of brick to one of sulphate of lime, spread as concrete on a centre; a large quantity of the slag from the potteries at Lambeth has been used, and forms an excellent material for the purpose. The spans are for the most part eight or nine feet, the thickness at the crown being four inches, increased to about nine inches at the haunches.

The drawings show the construction of the floor of the wards. It was thought desirable throughout the wards to have flat ceilings, but throughout the corridors and a great portion of the hospital the arches and girders are left to show the construction, the soffits of the arches being finished with a setting coat of plastering. The joists and sleepers, or concrete and paving, are laid on the top of the Dennett arching in the ordinary way. The wagon headed ceiling of the chapel, and the groining of the aisles is also executed in the same material, the aisles having stone ribs. The thickness in the panels is five inches and in the stiles ten inches. The reason which induced me to adopt this mode of construction for the Chapel roof was not only the satisfaction of having a real sound solid construction, but it afforded an opportunity of carrying up several flues to the apex of the roof which must otherwise have cropped up in an objectionable mode on the balustrading. The flues are carried across the groining of aisles on the back of the main ribs, then up the piers of clerestory walls, and again on the back of the main roof, provision being made for sweeping at certain points easy of access. I may here mention that the flues from all the low buildings are taken across the corridor ceilings, and carried up with the main building, thus avoiding all risk of smoke and disfigurement. The ceiling of the Governors' hall is constructed with iron girders and Dennett arching for the same reasons. The flues for the rooms on the lower floors had to be disposed of, and instead of interfering

with the parapet and balustrading were carried over the back of the cove, and taken out of the roof in the ordinary way. The "Dennett" material is certainly very handy in execution: it accommodates itself to any form of arch or groin: it is strong, has great resistance against fire, and when set, does not exert any lateral pressure, but care must be taken, and a liberal allowance made for expansion during the process of setting. I believe it is as cheap if not cheaper than any other fireproof construction. The superficial area of arching used at the hospital in floors and flats is about three hundred and thirty seven thousand feet.

The rivetted iron girders, of which there are about 1,250 tons, were made in Belgium at the Sclessin Works, and although not quite so neat in finish as one would wish, (many being exposed to view), yet at the same time they are composed of excellent material, and stood the proof tests well. They were delivered very regularly, and the delay which so often occurs from the non-delivery of iron-work was avoided. The flat roofs over low buildings and corridors, which in many parts form terraces of communication, are constructed in a similar way. The surface of the arching is covered with concrete, laid to the required fall, and then covered with asphalte—"Pilkington's Patent," which consists of the introduction of a layer of felt between two coats of asphalte. The lower coat is laid in Polonceau, about half inch thick, and the upper coat in Seyssel, half inch thick, with flashing of the same material. The whole, as well as the paving in the basement, has been executed by Mr. Pilkington in an excellent manner. The paving and channel stones used in the areas are the Patent Victoria Stone, composed of granite chippings and Portland cement cast in moulds, and indurated by a process somewhat similar to Mr. Ransome's. It forms a capital paving, and a considerable saving has been effected by using it in lieu of rubbed York. The traffic in the areas is of course unimportant, but the paving in question has been severely tested in the Poultry and on Blackfriars Bridge, and is standing the test well. The corridors are paved with tiles one foot square and inch thick in alternate squares of red and buff, with black borders. They are executed in Ransome's material specially indurated, and when one considers that this material is found most effectual as a grindstone, I am induced to expect that it will stand the effect of friction as well, if not better, than any natural stone. The cost of such paving bedded and jointed in Portland cement is very moderate. The quantity required will be about 30,000 feet, and I do not think so good an effect could be produced in any other material with equal durability at so small a cost. The floors of the wards are laid with wainscot as being non-absorbent, and the walls are plastered with Parian cement with the same object. It has been endeavoured to incorporate a tint with the finishing coat of the Parian, with a view to avoid the glare of the natural white color, and of painting hereafter. Certain experiments were tried, and it was found that with a backing of Portland cement and a setting coat only of Parian, a more uniform tint was produced than by using Parian throughout. Although great care has been taken in the manipulation, the result is not wholly satisfactory. Had we been able to wait until the walls were more completely dry, a more uniform tint would probably have been produced.

The ward windows are constructed in three divisions, as shown on the drawings, the lower part being hung to open in the usual way, and the upper sash drops to the depth of the transom, which is quite sufficient for clearing the upper stratum of air in the wards. The whole of these sashes and frames, and the greater portion of the doors were made in Sweden by the firm of Messrs. Ekman. My assistant Mr. Harris went purposely to Sweden to inspect the works, and brought back a most satisfactory report of the machinery, drying chambers, and general capabilities of the establishment for turning out good work, and the result has fully justified the confidence placed in them.

The ground floor of one of the pavilions has been used up as a drying room, by building up temporarily the various openings in which all the floor boards and other joiner's work have been thoroughly seasoned. One of the many newspaper critics seeing these openings built up, regretted that the

Governors were unable to utilize the whole of the Hospital, and that some of the wards had consequently been built up. A little enquiry would have enlightened him and explained the reason of the temporary blockade.

In designing the joiners' work, all moldings and quirks have been dispensed with as far as possible, as such parts only afford harbour for vermin. The wainscot floors are tongued with hoop-iron, the nail holes stopped with colored putty, and prepared for waxing and polishing. The windows of the pavilions are glazed with plate glass, with a view to a more equal temperature, and the corridors are glazed with flatted crown.

The warming and ventilating arrangements are indicated to some extent by the drawings exhibited this evening. It was determined to depend as much as possible on natural ventilation, avoiding all costly arrangements and fanciful theories, at the same time providing the means of changing the air during cold and boisterous weather and at night. The main extraction shaft is carried up in the well-hole of the staircases, and in this is placed the smoke-flue from the boiler, consisting of a wrought iron tube 15 inches diameter. The boilers for warming purposes would not of course be available in the summer, but the furnace for the supply of hot water and baths would be continuous in its operation. In the upper part of this shaft are also placed the hot water cistern, and if found necessary, hot water coils will be added to assist the rarefaction. Shafts are carried from the ends of all the wards, both at the ceiling and floor level, and from the centre at the stove shaft hereafter mentioned, communicating with a horizontal trunk in the roof, which trunk is connected with the heated shaft previously referred to. To replace the air thus extracted, fresh air is introduced by means of zinc tubes laid between the "Dennett" arching and the floor boards communicating with the stoves and hot water coils, thus passing over a cool surface in summer, and tempered in winter by contact with the heated surfaces before entering the wards, the whole admitting of regulation by valves. Each pavilion has its independent means of warming and ventilating, avoiding as much as possible all complication in the arrangement, but the pipes are so arranged that in the event of a break-down in any one block, its neighbour can come to its assistance during its temporary failure. A chamber is formed under the ceilings of the corridor in basement and ground floor, into which the whole of the rooms in the low intermediate buildings forming the out-patients' and casually departments are ventilated, and this chamber communicates at each pavilion with the main extraction shaft before described. The wards generally are warmed by three open fire-places, aided in cold weather by an auxiliary system of hot water. The corridors and staircases are also warmed by hot water. The open fire-places stand in the middle of the wards with vertical shafts. These fire-places might have been arranged against the outer walls, but bed space would thus have been sacrificed. The stoves might have been placed as they are, but with descending flues to the outer walls. This, however, would have involved great complication in the arrangement, risk of smoke and difficulty in sweeping, and the piers already small enough would have been so riddled with flues that they would have been unequal to carry the weight imposed. It was therefore thought best to carry up a vertical shaft throughout. It may detract somewhat from the appearance of the wards, but it has, I think, great compensating advantages. The shafts are constructed, as shown on the drawings, with an outer case of cast iron, and an inner wrought iron smoke tube 15 inches diameter. The hot metal does not, therefore, come in contact with the atmosphere of the wards, but the space between the two tubes becomes an efficient ventilating shaft, which is connected as before with the main trunk in roof. The smoke tube is carried down to the basement, and will be swept from below without disturbing the wards. The whole arrangement is capable of easy removal for repair. A cast iron socket is built into each floor, supported on two small bearers running from girder to girder, and the "Dennett" arching is made good to the same all round, thus avoiding any communication from floor to floor. The outer casing is

of cast iron, put up in pieces and bolted together, and is easily removed at any time should it be necessary to repair the smoke tubes. In the upper story the iron casing is discontinued, and a brick casing built on the concrete floor, which is more convenient for passing through the roof and carrying the external shaft. It will be observed that the three stoves go into one flue. This is made of ample dimensions, and a valve is provided at each stove to close the connection with the flues when the stove is not in use. As far as it can be tested in the present unfinished condition of the work the arrangement works satisfactorily. The stoves are formed with an air chamber at the back, having a large heating surface of metal (but which cannot be heated sufficiently to vitiate the air) standing in a pan of water, somewhat similar to the Gurney stove. The ventilation of the water closet and lavatories is entirely independent of the wards, and is carried up the shaft in the river turret, in which are placed the hot-water tanks for supply of baths and coils. The stone shafts at the angles form the termination of the foul linen and dust shoots, which are carried right up to the external air. The ventilation of the museum and school buildings is on the same general principle, the ventilating and smoke shaft being contained in the tower at the southern end of the building. The whole of the warming and ventilating works have been most satisfactorily carried out by the well-known and experienced firm of Haden and Son, of Trowbridge, and I am glad to bear testimony to their ability and the careful and considerate attention to all works entrusted to them.

The risk of fire is reduced to a minimum, but considering that an alarm even of fire would act most injuriously on many cases, a system of fire mains and cocks is provided throughout the building. The cocks admit of being served either from the rising main or from the large tanks provided in the towers. A special main has been laid by the Southwark and Vauxhall Company to supply the building, and a constant service will, it is expected, be supplied; but in the event of any accident happening to the main, provision is made by an arrangement of back valves to supply the fire cocks from the tanks. These arrangements have been carried out by Messrs. Shand and Mason, whose name is a guarantee of their efficiency, The gas services have been executed by Messrs. Strode, and although not calling for any special description, I may say that they have been carried out in the usual satisfactory manner by that firm.

The lifts, of which there are one to each pavilion, demand a few words of explanation. They are constructed upon the hydraulic ram principle. A boring was made to a depth of 70 ft., and lined in the usual manner for about 22 feet through the gravel with cast iron cylinders to keep back the water, and from this point to the bottom through the clay the well is lined with brickwork. In this well is sunk a cast iron cylinder, 11 inches internal diameter, strongly bolted together in 9 feet lengths : and within this again comes a hollow ram, 9 inches diameter, working through this cylinder, screwed together in 9 feet lengths. On the top of the ram the ascending room is attached, consisting of a strong iron frame with iron roof, all strongly trussed together and lined with match boarding. At the top and bottom of this room, on each side, are V guides, lined with gun metal, the top ones having springs to prevent oscillation or sudden shocks. At each side are suspending irons, to which are attached strong chains passing up a groove in the brickwork and over wheels, 3 feet 8 inches diameter, to the counterbalance, on each side; these counterbalances work in recesses, and are grooved to run in guide irons. The guide bars for the ascending rooms are of cast iron, placed the whole height to ensure a steady movement. A gear rod passes through the cage to control the lift, and self-stopping gear is attached. The lifts are worked by fall of water from large tanks fixed in the roof of each block, 104 feet from basement, each tank containing 2,500 gallons. The stroke or rise of each lift is 63 feet. The pressure of water is 45 lbs. per square inch, and the lifts are calculated to raise six persons each time. This principle has been adopted as affording the most perfect safety attainable. The over-head gear is placed at the sides in a chamber specially provided, so that in the event of any fracture thereof, no damage would arise to

the cage. There is also one food lift to each block. They are upon the rack and piston principle. The machinery, which is in the basement, consists in each case of a cylinder, 11 inches diameter, with piston and rack working in it, with tooth wheel and large drum wheel, on which is coiled the wire lifting rope, passing to the top of the building and over a one-grooved pulley to the cage, which has guides top and bottom; this cage runs in T iron guides, fixed in each side of walls, from top to bottom of lift hole. A separate wire rope is attached to top of cage, passing over grooved top wheel to the counterbalance, which is also guided on each side by angle iron guides. The lift is worked by a rod passing up at the corner and communicating with the valve at bottom. The weight intended to be raised is 1 cwt. The height is 63 feet, and these lifts are worked from the same tank as the passenger-lifts. They are easily controlled at any floor, and stop themselves at the highest and lowest points. The whole of the lifting apparatus has been specially designed and carried out by Fred. Colyer and Co., Engineers, St. Mary's Iron Works, Leman Street, London, the whole of the work being of the most substantial character, and nothing has been neglected to ensure thorough efficiency, combined with perfect safety.

The electric communication has been executed partly by Messrs. Reid, Brothers, of the City Road, and partly by Messrs. Moseley, the ornamental ironwork by Messrs. Skidmore, and the cooking arrangements by Messrs. Benham and Son.

In conclusion allow me to say a few words as regards the cost. The ultimate cost exclusive of the site will probably be about £400,000., including foundations and fittings, or £650. per bed, which in the absence of any detailed explanation appears to be a large sum; but if all extraneous buildings are allowed for, and the cost of one pavilion taken, which accommodates 111 beds, it will be found that the amount would be reduced to £250. per bed, and considering the cubic allowance of space, the number of attached rooms provided and the character of the work generally, such amount does not appear to me to be excessive. The cost of the building, exclusive of the concrete foundations and the enclosure railing, is about 9*d*. a cube foot. The contract among other things provides a large medical school building, a building for the training of nurses, large administrative offices for the civil department of the hospital, five residences and extensive out-patients department, and the enclosure of $8\frac{1}{2}$ acres of land, with stone curb and iron railing and parapet walls.

I have now only to bear testimony to the excellent manner in which Messrs. Perry have carried out the work, and to thank Mr. Bullivant, the Clerk of Works, and all parties who have assisted me, for the zeal and ability with which they have performed their several duties. I fear I must have exhausted your patience by the dry details which I have brought before you; but whatever may be the architectural merits or defects of the building, the magnitude of the structure, and the important position it occupies, renders it perhaps not altogether an unfit subject to be recorded in the Transactions of the Institute. At all events you will I am sure agree with me in the expression of a hope that it may be effectual in alleviating the sufferings of the poor, and in advancing the noble arts of medicine and surgery.

The PRESIDENT.—Whatever difference of opinion there may be relative to the merits of the pavilion or other form of hospital, or on the vexed questions connected with this subject, nobody can doubt the thought, and care and study, which Mr. Currey has bestowed upon it, and we are much indebted to him for the trouble he has taken in putting on paper a very comprehensive and consecutive detail of this most interesting building. There are several gentlemen present (and amongst them members of the medical profession) who have paid a great deal of attention to this subject and have shewn great interest in it, and I hope they will be good enough to give us the benefit of their remarks.

Dr. BALFOUR, Visitor (responding to the President's invitation) said.—Since you have done me the honor, Sir, to call upon me to speak, allow me in the first place to thank you for having given me the

opportunity of hearing so able and interesting a paper: and in the next place, to thank Mr. Currey for having kindly given me permission personally to inspect the building to which it refers. I have but little to say, except that I was much struck with the great care taken to provide for all the requirements of the medical staff and the schools of the hospital, and the foresight shown in the arrangements for placing the patients in circumstances most likely to conduce to success in the treatment of their diseases. Perhaps it is the highest compliment I can pay Mr. Currey, to state that on one point only did I find anything that did not fully come up to my expectations; and that was in respect of one portion of the system of ventilation. I am not prepared to endorse the opinion that the plan of ventilation by shafts in the centre of the wards is perfect, because I fear in summer time, when the fires are not burning, and consequently when there is no heat in the centre tube, the foul atmosphere of one ward may possibly get into another. As I did not see the drawings of that part of the plans which relate to the arrangements for the ventilation by means of these tubes, I may be speaking under a mistake; but so far as I could judge, there is nothing to prevent the foul air of one ward getting into another, if there happens to be a difference of temperature between the two, or a current of air passing through one of the wards, which might have the effect of drawing part of the supply of air for the ward from the tube. But as that is the only point on which I differ materially from the architect, I may be permitted to repeat, that the whole of the arrangements of the hospital and school appear to me to be of the most satisfactory character.

Mr. EDWARD HALL, Visitor.—I think Mr. Currey has not quite correctly described the arrangements of the Lariboisière Hospital in Paris. That hospital has the ward-blocks and other buildings all surrounding a central court; whilst, I believe, Mr. Currey described the ward-blocks as extending right and left of, and at right angles to, a long connecting corridor. The latter arrangement has been carried into effect in two or three hospitals in Great Britain,—the first case in which it was adopted being the Infirmary at Blackburn, which I visited at the time: but the Lariboisière plan is that of a central court, with corridors all round, and with the administrative buildings at the ends, or north and south, and the ward-blocks extending east and west. I think it probable that that arrangement is worth a little more attention than it has received in this country, because the plan is considerably more compact, and it is possible to place the kitchen in a more central situation. There is another point in connection with hospital-construction which is worthy of consideration—that is the advantage, or otherwise, of coating the walls of the wards internally with Parian cement. At the time when the question of the construction of hospitals was assiduously discussed in this country, it was considered by many that Parian cement was the best material, and that in all cases the endeavour should be made to have highly-polished surfaces to the walls: but in a very important hospital, that of the Chorlton Union, near Manchester, the walls were coated with lime-white. In that case, the reason was, that the funds would not allow Parian to be used: but it has been suggested of late years, that it would be very much better to avoid the use of Parian cement (which, good as it is, is said to be liable to absorb miasmas), and that if lime-white were adopted, it would be possible to renew the coating, whilst, moreover, the lime-white would be a preservative from infection,—which Parian cement would not be. There are many other points which Mr. Currey, perhaps thinking that we were pretty well acquainted with, only touched upon. The question of cubic feet of space is an important one; and I think that Mr. Currey has given a larger number of cubic feet per patient in his wards than has been given in any previous building. With regard to distance of ward blocks from one another, that is important in connection with this building; because though the distance is greater than in any previous case, yet in consequence of the height of the blocks in St. Thomas's Hospital, the question of sufficient distance for a like building, is one which may be worthy of distinct consideration.

Dr. FITZGERALD.—I can only say, I went over this building to-day, and was very highly pleased with all I saw. I was myself educated at University College, and this hospital appears to me to bear very favourable comparison with it.

Mr. BRUDENELL CARTER, Visitor, said.—Mr. President, you have been so good as to invite the expression of opinion from members of the medical profession, and I have had the advantage not only of hearing Mr. Currey's remarkably lucid paper to-night, but on more than one occasion of accompanying him over the building, and I have watched with interest its progress from its early to its present advanced stage. Shortly after the construction of this hospital was determined on, a note of alarm was sounded by a great medical authority now no more, regarding the building of hospitals as permanent structures. The late Sir James Simpson expressed his fears that hospitals in the course of years became saturated with the miasmas thrown off by the sick, and stated that the best way to construct hospitals was to build them in a rough and temporary manner: so that after a certain period they might be taken down, destroyed, and another building erected on a different site, and built in a similar way to the first. The great weight of Sir James Simpson's name attached more importance to this statement than I think was warranted by the arguments and facts advanced in support of it; and as St. Thomas's is the first instance we have since the publication of this statement, of a hospital seemingly calculated to endure as long as this city, it will be satisfactory to the architect to hear that it is the opinion of the medical profession generally that Sir James Simpson sounded an unnecessary note of alarm, which I believe no facts will justify, and that with proper attention to disinfection, and cleanliness and ventilation, this great building may be kept for all time in a state of as perfect wholesomeness as on the day when it is first occupied. My colleague, Mr. Holmes, has published an article in the *Lancet*, upon the views of Sir James Simpson on this matter, which I think the architectural profession will read with pleasure as bearing upon this point. The use of lime white as a coating for the walls of the wards has been referred to, and a notable instance of this is afforded by the hospital at Hampstead, which was erected by the Parish of St. Pancras, and has passed into the hands of the Metropolitan Asylum Board. In that case it was done as a matter of economy, and I think with due care in proper cleansing it is possible that no harm may arise from it. We must remember, however, that such walls cannot be kept clean by frequent washing. They must be scraped, and we learn by experience that the disturbance of accumulated morbific matter by scraping is a process attended by many and serious dangers. Like Dr. Balfour I have no criticisms to offer upon the smaller details of the building. I may venture an opinion that according to the present arrangement there will not be sufficient light in the operating theatre; that I imagine is a point of detail that can be easily remedied. We know that surgical operations require a good deal of light; and in this case I think, owing to the great height of the roof, that a larger sky-light will be required before the surgeons feel at home in their new operating theatre. I would heartily congratulate Mr. Currey on the success of his building, which I trust will fulfil the high purposes to which it will be devoted, prove a blessing to the classes for whose benefit it was instituted, and promote the advancement of medical science in this country.

Professor DONALDSON, P.P., Hon. See. For. Corr.—Mr. President, from your great experience in this class of buildings, and from the description given by Mr. Currey, you will, I am sure, recognise the deep study which he has bestowed upon this important building, and congratulate him on the success which has attended its execution. It is quite true that it differs in some particulars from the Lariboisière Hospital, but the same principle is mainly carried out. From the great length of the plot of ground it was impossible to compress the arrangement into a square shape with a central court. The criticism on the part of the previous speaker with respect to the supposed insufficiency of light in the operating theatre can be easily remedied by the enlargement of the aperture, the light being in

the right place—viz., direct from the sky on to the object to be operated upon. I beg to propose that we tender our best thanks to Mr. Currey, for the very lucid and instructive description of his noble hospital, with which he has favoured us.

Professor KERR, Fellow.—I have very much pleasure in seconding the vote of thanks. We must have all felt whilst Mr. Currey was reading his paper that he is a singularly happy man. For him to have got through this great work without, as far as we have heard a single difficulty, is a circumstance so unusual in our profession, that we may congratulate our friend not only upon his own good fortune, but also upon the credit thus conferred upon the profession which he represents. The reason of this may partly be that our friend has had a commission so very liberal in its character; but he has also brought to bear upon the execution of it not only a very thorough acquaintance with the subject, but a certain straightforward mode of doing business, and the avoidance of a certain straining after effect, which two considerations go very far, as we see by the example of our friend, to ensure success. The description he has given shews that he has had, from the foundation to the summit, but one object in view, viz. to do the work with the utmost substantiality, and the utmost simplicity, and I think never in the course of my experience have I heard or read a description of a building carrying more completely to my mind the appearance of its having been done well and to the very best purpose. The site is of course one which has afforded our friend great freedom with regard to space,—a thing which too seldom falls to the lot of an architect designing a large building of this class. He has availed himself of that freedom of space in a most intelligent manner, and I think, from what I hear, that public opinion is universally inclined to consider this hospital to be a *chef-d'œuvre* of its kind; so that, in fact, it may be called one of the most popular works of the day with regard to its efficiency and the likelihood of its proving to be a success for many years to come. There is one point on which I should like to say a word, more particularly as I see my friend Mr. Ransome here, whose name has been so often mentioned in this room with great respect for the intelligence he has displayed in his invention of artificial stone. I would say a word with regard to Mr. Currey's use of artificial stone in this building. I confess once or twice, when I have heard the matter mentioned, I have felt inclined to doubt whether Mr. Currey was wholly justified, from an architect's point of view, in using the artificial stone in such a building; but after the description he has now given I for one am perfectly satisfied that the use he has actually made of it has fulfilled the proper intention of the material, and that he need not fear any architectural criticism which may be opened on the point. If I understand aright the capitals of the Corinthian columns are all of artificial stone; and I may take leave, for the credit of a most ingenious and enterprising man, to mention an incident which occurred with regard to these capitals. A certain stone carver had been promised, as he considered, all the carving work on St. Thomas's Hospital. He went on the ground one day, and complained that he was being badly treated, because that promise was not being fulfilled. The clerk of the works, who received him, did not understand what he referred to, until the carver explained himself thus: "Those Corinthian capitals which are beginning to be fixed are not carved by me." The clerk of the works acknowledged the fact, and desired that he would accompany him to a certain shed where he would see the whole number of capitals all ready for fixing. The carver had of course been misled by the resemblance of the artificial stone to the real Portland at a little distance; and he had now to acknowledge that he could with difficulty discover the difference close at hand. Now imitation so complete as this is to my mind perfectly fair and right; because what our friend manufactures is truly *stone*, not after the old mode of mere cement imitation and superficial resemblance or deception, but a legitimate substitute of sound structural character. I believe these capitals, for instance, are solid, or very nearly so, and they may fairly be said to be equal in all respects to natural stone. Mr. Currey mentioned the circumstance of this stone being superior to the natural

material in the form of grindstones. That is very remarkable. As has been remarked before in this room, Nature does not undertake to find us in grindstones; and we may therefore now go on to say that Nature is not to be discredited because of having suffered defeat in the field of grindstones at the hands of the ingenious Mr. Ransome. But I am pleased to hear that Mr. Ransome has now invented another description of stone, which seems to be superior to this; so that if Mr. Currey had waited a little longer he might have had to tell us of a material even better than that which he speaks of so favourably as he does. I have seen specimens of this new stone of the same kind as Portland; and I think when they come to be submitted to the Institute presently, you will be surprised at the extraordinary success of Mr. Ransome's new invention, which extends to the imitation not only of plain stone but of marbles. I understood Mr. Currey to say that his corridors are paved with Mr. Ransome's stone. This seems to me to be well worthy of consideration. We are all acquainted with tile paving, and for ornamental work perhaps nothing is better; but for paving on a large scale I understand Mr. Currey now to say that this artificial material is superior to York stone at any rate, and not merely economically but for wear. It is not a laminated stone like York, and that is perhaps the reason; but I should like to hear from Mr. Currey whether he thinks it equal as paving to Portland. Very important questions of hospital construction have been raised and ably discussed by medical gentlemen present. That which bears upon the question of the best wall surface for the wards has been brought out in a very interesting way. Some of us who have not given much attention to this particular point might have suggested that the ordinary rule might be applicable to hospitals; that Parian cement with polished surface, being non-absorbent, is liable to certain disadvantages with regard to the moisture from condensation: but gentlemen have to my mind so explained the propriety of using the polished surface that it seems perfectly satisfactory. I beg most cordially to second the motion of a vote of thanks to Mr. Currey for his paper, than which I have never listened to one more interesting to practical architects, or more creditable to the author.

Mr. J. JENNINGS, Fellow, said,—It would be presumptuous in me to criticise this able paper; but I think it is desirable to look at every point in connection with a subject under discussion. I have not heard on this present occasion that any other covering for walls than Parian cement or lime white has been noticed. Considering the great extent to which tiles and enamelled slates are used for coverings for walls, especially at Liverpool, and the question also whether glass tiles are not capable of being employed in the same way, I should be glad to know whether it has been considered that a covering of such materials, set in cement, would be suitable for the walls of hospital wards. It is clear a surface of glazed tiles or enamelled slates is not liable to either of the evils referred to in respect of any infection, but such a surface would be in a great degree liable to condensation of moisture; at the same time, I imagine that the provisions made by Mr. Currey may be sufficient to carry off the air in such a state as to prevent this disadvantage. On the question of ventilation generally, which is a most important one, I do not see in Mr. Currey's arrangements that he has made any special provision for carrying off the carbonic acid gas, which will have to be carried off, not from the upper, but from the lower parts of the building. Probably he calculates upon its passing out at the doors; but in summer time I conceive its egress would be dependent upon being drawn out by opening the window sashes at the top. I am not aware whether he considers opening the top of the sashes sufficient for the ventilation of the wards in the summer time. It is true that carbonic acid gas does not always remain at the bottom of a room, but will sometimes pass up to the top from various causes. Fires while burning would draw it off under ordinary circumstances, but I should like to know what provision is made for carrying it off when there are no fires. In practice it is found that when openings are provided near the ceiling, air, instead of going out through them, is likely to come in; and, therefore, while fires are

burning it is difficult to get such methods of drawing out the air to act, and at the same time to supply the fires sufficiently with air. In the case of Sir Charles Barry's dining room, it sometimes happened that the ventilation took the wrong turn and blew out the gas. The same thing has also happened where we have attempted to carry ventilation out by means of pipe or other flues adjoining and *heated* by the smoke flues; the draft now and then turns the wrong way and brings down the air. It is a question whether we should not provide for the admission of air down from the roof by the same sort of plan as Mr. Currey has provided for taking it out. I heard of a case a short time since in which external air at a temperature of thirty degrees was brought down at the side of the flue, and entered the room at fifty degrees, half way between the ceiling and the chimney opening, and thus the warmth of the room was considerably increased.

Mr. C. FOWLER, Fellow.—I cannot refrain from expressing the great interest with which I have listened to this paper, which appears to me to suggest three subjects for congratulation. In the first place, we may congratulate our friend, as I am sure we all do most heartily, on the satisfactory completion of such an important monument, for it deserves that name. In the second place, we may congratulate the profession generally upon the liberality which the Governors of the hospital have displayed in enabling the architect to carry out such a building; and the third party for congratulation is, I think, the public upon having received so important an addition to the monumental objects of the metropolis. The subject of hospital construction I had occasion to consider about twenty years ago. At that time this subject was not so well understood or settled as at the present time. I suppose we may consider, after a great deal of discussion during that period, we have at length arrived at some tolerably definite ideas upon it. But twenty years ago it was, as many present are aware, a very open subject as to what the arrangements of a hospital should be, and the particular building which I have in my mind was the subject of a great deal of discussion; and, eventually, the wrong plan was adopted. The architect in that case was restricted as to the expenditure to the extent that the cost was under £100. per bed for everything; and the cost per foot cube was about 5½d., or only a little more than half what it has been in the present instance. We now know pretty well that that scale is much too low to provide an efficient establishment of this kind, and is matter of congratulation that we have made in the period of twenty years satisfactory progress in our knowledge of this subject. It is too late, even if one could do so, to enter upon any criticisms of this work, but I could not help feeling that it was altogether a subject for congratulation that more enlightened views on the subject of hospital construction obtain in the present day to what was the case twenty years ago.

Dr. MASSY, Visitor.—In obedience to the request of the President I shall make a few observations upon the questions under discussion. I shall not attempt to enter into the numerous architectural merits of this hospital, but beg to make a few remarks upon portions of the ward construction which I trust will not be deemed inapplicable. Like the rest of the building the wards have, in my opinion, many great merits. I think the arrangement for cutting off the lifts from the wards by two doors, and thereby preventing a common atmosphere in the wards of each pavilion, is a great advantage. The floors of the wards being closely jointed oak, if well waxed and rubbed, will be as non-absorbent as the walls; and I quite concur with the speaker who considers non-absorbent walls the best for hospital wards. The water-closets, lavatories, and baths, at the ends of the wards are well situated and well ventilated, and their arrangement such as to prevent any nuisance arising from them to the wards to which they are contiguous. Each ward is intended, as far as I can gather from the description, to be self or independently ventilated; but there are some features regarding their ventilation which I should like to have heard more particularly described. For instance, Mr. Currey did not state the proportion of the area of inlet and outlet air apertures, though no doubt it has been arranged on some definite

relation each to the other, as well as the area of both, either to the size of the wards or to the number of occupants they are intended to accommodate. The general plan of the ward ventilation I should also like to have heard more detailed. It appears to me that it may be considered a summer and a winter system. As the wards are built upon the pavilion plan, which I believe to be the best, by opening the windows in summer good ventilation can always be obtained. The winter ventilation, as I understand it, does not appear to me so good. There are two modes of inlet, one along the floor in connection with hot water coils, and the other passing direct to the stoves, in connection with which the air is warmed before distribution to wards; thus all the air admitted is heated. It appears to me that, unless care is taken, such a system will be apt to render the air too dry for the use of the patients. There are two systems of foul air outlet, one in the side walls at the end of the wards, and the other round the chimneys near the ceiling. Those at the ends of the wards pass into long horizontal flues which communicate with a common flue from which the extraction is made by heat, somewhat analogous to the system known as Jebb's, which has been adopted in many jails, and which I do not consider well suited for hospitals. With regard to the outlets at the ceiling round the chimneys, it appears to me that part of the heat from the fires, and part of the fresh air warmed by the stoves will pass up direct through them, without being distributed in the wards, and that this may be augmented when the gas is lit, as the gas jets are situated round the chimneys, and will tend to increase the upward outlet current; and if these outlets round the chimneys have communication with those of the different wards in each pavilion, I think it very objectionable.

Mr. CURREY (in reply upon the discussion), said—I will say one or two words in reply to the observations that have been made. In the first place Dr. Balfour referred to the shafts in the centre of the wards. I may say with regard to those that we do not depend principally upon them for ventilation. The fact is, the outer casing was put up with a view to prevent the air being deteriorated by contact with the smoke tube from the stoves. Having that space it seemed a pity not to use is as an extraction shaft. The main ventilation is at the two ends of the wards at the top and bottom, and those shafts are much larger than those provided in the centre, and the rarefying power in the tower will be in operation in summer and winter, and day and night. With respect to the carbonic acid gas referred to by Mr. Jennings, which is no doubt very capricious, we have made arrangements for carrying that off, either at the top or the bottom of the wards. The Parian cement question has, I think, been fully disposed of by Dr. Carter and other speakers. A similar material was used on the walls of the new wards of the old hospital, and those were washed down every summer, and that was found to answer satisfactorily, and in my opinion it is much preferable to the rough surface of lime white. With regard to Mr. Jennings's suggestion as to the use of tiles, I think the number of joints in tile surfaces is objectionable as being harbours for vermin; the use of slate in larger pieces would get rid to a great extent of that objection, but it becomes expensive. I am sorry I am not in a position to give Dr. Massey the information he asked for as to the relative proportions of inlet and outlet; but as far as I can recollect the inlet is about fifty inches to each patient, and the extraction shaft is much larger than that. With regard to the amount of light in the operating theatre, if it is found that the present supply is insufficient, it can very readily be increased, because there are a number of blank windows at the top, which will be available for the purpose.

Dr. BALFOUR.—Is there any arrangement to prevent the foul air of one ward getting into another ward through the centre tube? as I imagine under certain circumstances that might be the case.

Mr. CURREY.—Looking at the passage where it passes from one floor to another the air must go up a considerable distance and come down again, before what Dr. Balfour alludes to can take place, and the centre shafts are all connected with the main extracting shaft.

The PRESIDENT.—As the hour is growing late, I will not detain you a minute before asking you to pass a unanimous vote of thanks to Mr. Currey. I would only say, having myself been frequently consulted on the matter, my own opinion goes in favour of the use of Parian cement for the walls of the wards of hospitals. It was done in the case of the Middlesex Hospital, though under the disadvantages of having an old building to deal with. All that is done, is to have the walls thoroughly cleaned down once a year, and to do that the beds are either taken out of the ward, or placed in the centre out of the way of the washing. We have had no difficulty from condensation of the vapour; and I cannot conceive that the comparatively rough surface of lime-white, however treated, can be a good thing. I have had the pleasure of going over this hospital with Mr. Currey, and I was struck with the absence of all unnecessary ornamentation involving a large expenditure, and this in such a building, appears to me a most judicious point in Mr. Currey's treatment of it. You will, I am sure, all join me in a most cordial vote of thanks to Mr. Currey, for his most interesting communication.

The vote of thanks to Mr. Currey having been put by the President, it was carried by acclamation, and Mr. Currey expressed his acknowledgments for the high compliment that had been paid him.

A LETTER RESPECTING THE TOMB OF CHARLEMAGNE, AT AIX-LA-CHAPELLE.

The following letter was read by the Honorary Secretary For. Corr. :—

Bonn-on-the-Rhine, January 11th, 1871.

Sir,—I have received from Aix-la-Chapelle your interesting paper on the tomb of Charlemagne, which was supposed to be intended for me, and for which I am very much indebted to you. I quite agree with you in the opinion, that the tomb could not have been in the centre of the Octagon. Some traces of it would surely have been discovered in 1861, but having been an eye-witness of the researches made at that time (Prof. Zwirner, whom you mean, I suppose, had nothing to do with them, and was then dying), I am fully convinced that there could not have been a vault such as has been described, or even a much smaller one. Your own suggestion, that the body was originally preserved in a vault built under the altar, would appear to me to give a most satisfactory answer to the often debated question, if I knew any example of the remains of one not revered as a Saint having been placed under an altar, a thing quite contrary to the ideas of the Church. Charlemagne was not canonised in the time of Othow III. as you say, page 41, but in that of Frederick I., as is correctly stated, p. 38, not by Pope Alexander (then at war with the Emperor), but by the Antipope Paschal III; in fact this canonisation has never been regularly recognized by the Roman Church. It was only then the body was removed from the original tomb. It appears to me very probable, that the tomb may have been quite destroyed when the present choir was built (XIVth century), but in this case I think it could have been nowhere else but in the segment of the Octagon, opposite the entrance, before the ancient altar. At any rate, I believe the narrative contained in the chronicle of Novalesa, of the aperture of the vault under the Emperor Othow III. to be greatly exaggerated, it being altogether impossible, that the traces of such a vault, as is described there, could have completely disappeared.

You do not seem to have been informed of the researches undertaken five years ago, when, outside the Octagon, adjoining the buildings erected by Philip of Hohenslaufen, Barbarossa's son, they discovered the foundation walls of a small quadrangle with an apsis, which at one time was thought to have been the tomb; an opinion apparently corroborated by the remains of an inscription, which was afterwards proved to be counterfeited !

The columns of the gallery of the Octagon returned from Paris have been replaced a quarter of a century ago, when, instead of those remaining in the Louvre, the late King of Prussia presented the Church with splendid granite columns.

Six years ago, I read in Rome in the Papal Archæological Academy, a paper on the Tomb and Church. I very much regret to be left without a single copy of this paper, printed in the "Giornale Arcadico," but now reprinting in the sixteenth volume of the Acts of the aforesaid Academy.

With sincere thanks, I remain, Sir,

Your most obedient,

ALFRED DE REUMONT,

Chamberlain to the King, late Prussian Minister Resident at Florence and Rome, LL.D., M.A.

The following particulars also seem necessary to supplement the information contained in Professor Donaldson's Memoir.

Monsieur Arendt positively states in his pamphlet " que les fouilles en 1861 eurent lieu en presence de S. E. M. d'Olfers et sous la direction de l'architecte de la ville, et *avec l'assistance de l'architecte conduisant les travaux de restauration de la Cathédrale*," who was Prof. Zwirner.

The sarcophagus with the Rape of Proserpine (Note, page 39) stated by Dittmar to have been removed to Marseilles by the French is now at Aix, one of the less relics, and is engraved, p. 23, of Canon Bock's illustrations.

The statement, p. 41, with regard to the regalia preserved at Vienna is not sufficiently full. According to Baedeker, they consist of the crown, sceptre, imperial globe with cross, dalmatica, alb, stole, girdle and sword (Joyeuse); also the relics, which were anciently exhibited at the coronations.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, 6th Feb., 1871, an Abstract of the following Paper was read:—Edward I'Anson, Vice-President, in the Chair.

ON THE MATHEMATICAL THEORY OF DOMES.

By Edmund Beckett Denison, Esq., LL.D., Q.C., F.R.A.S.

Perhaps in this age of iron no great dome of masonry will be ever built again. Yet we must all remember that the two iron and glass domes of the Exhibition of 1862, of which one is now on a much handsomer building at Alexandra Park, though as large as any in the world, or that oval dome of the new Albert Hall which is twice as large, being 220ft. × 185, have excited no such interest as is still felt everywhere in the comparatively unscientific fabrics of the Pantheon and St. Peter's at Rome, the Cathedral of Florence, the Gol Gomuz of Becjapore, and even the flat segmental domes of Constantinople and St. Vitale at Ravenna, which is made of pots. I suppose everybody will agree with Mr. Fergusson's dictum that a dome is the most perfect roof that has ever been invented, especially on a large scale. But the cracks and bands of St. Peter's, the immense thickness of the Indian domes and the Pantheon, Wren's evasion of the difficulty at St. Paul's, and the non-existence in the world of any very large complete dome of moderate thickness, have raised an impression that no such dome can exist, and that large hemispheres of masonry must either be enormously thick and heavy, or else must depend so much on ties that we may as well build iron domes at once.

The subject has naturally been discussed here several times; and I see that on nearly every occasion a wish has been expressed for a complete investigation of it, or for what was called a Monogram on Domes, which shall be at once mathematical and practical. Mathematical writers have hitherto been content with proving what can be proved much more simply, and is practically known to every man who ever turned a flat segmental dome over a well; viz. that such a dome, of about half the height of a hemisphere, has no tendency to burst if it is sufficiently tied at the bottom. And there they have stopped, and left us to conclude—and have themselves asserted—that below the point where the natural stability of a segmental dome ends we cannot continue the hemisphere at all without the aid of ties or bands, or reliance on the tenacity of cement and some very great thickness, almost enough to make the dome contain a cone. Indeed that was precisely the conclusion arrived at (without mathematics or experiments) in the paper read here by Professor Lewis in 1859, who says (p. 117), 'He believes that the real secret of constructing lantern-bearing domes of large size,' and others in a less degree, 'is to make them approach so closely to the conical form that their 'section shall include that powerful outline within their thickness,'. . . 'although by careful atten-'tion to the goodness of the materials and the general bond of the work, it may no doubt be made 'secure with other outlines,'. . . . 'but that any departure from this,' the thickness requisite to contain a cone (which would be above 14 feet in a dome 100 ft. wide) 'entails risk.' Mr. Fergusson on the other hand says 'it is as difficult to build a dome that will fall as a vault that will stand' (*Handbook*, p. 441). Between these widely differing views it is time that we should come to some more definite conclusion as to the true conditions of stability.

My attention happened to be turned to the subject lately, and on finding that there was really no definite information on it to be found in books, I set to work to calculate it for myself, with no

expectation, I confess, that it would take as much trouble as it has; partly no doubt from my mathematics being somewhat rusty; but I am consoled by finding that a friend of mine who is more handy with those tools than I am, and we shall see, another mathematician also, fell at first into the same mistake as I did, and afterwards discovered that the problem is not so easy as it looks. Since this paper was substantially written, Mr. E. W. Tarn, a member of your body, has sent me a paper of his, in the 'Engineer and Architect's Journal,' of Feb. 1870, containing harder mathematics than I shall venture on; but even he does not attack the fundamental problem of dome-building, the thickness requisite to make a dome of given size and shape stable when tied only at the base. By the word 'stable' I shall always mean that, and assume that the dome is deriving no help from 'friction and stiction,' or may be considered as cut up by any number of vertical cracks like meridians into those narrow slices which mathematicians call *lunes*, as they are like a young or old moon, except that it is only seen obliquely.

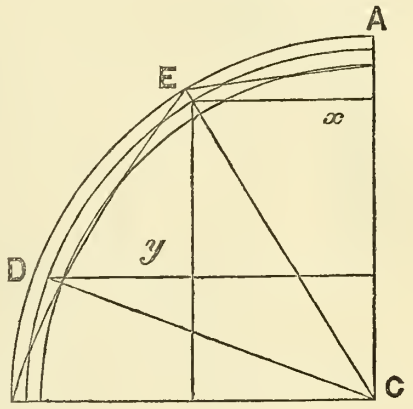
You will find in the 'Penny' and 'British Cyclopedias' the algebraical result of a calculation by Venturoli many years ago, as to the proper thickness of a dome. But I confess I am unable to attach any practical meaning whatever to it, and it has not been adopted in any modern mathematical book that I have seen. I observe too that these and other writers say 'the theory of the dome is easy compared with that of the arch:' and so it is, down to the point at which they stop. You will see whether it is so beyond that point. So far as I can see, the problem is altogether insoluble by any except tentative and approximate methods. The introduction of the thickness so deranges all the natural relations of sines and cosines, that the formulæ soon become unmanageable for any direct solution; and that is doubtless the reason why it has been left untouched in mathematical books. My object is not to perform any mathematical feat, but to obtain practical results free from any errors except small ones, and those always on the safe side. If this mode of treating a mathematical problem appears strange to non-mathematical readers, they may be informed that some of the greatest problems in astronomy can only be solved by approximation, including all the lunar and planetary disturbances, by one of which Neptune was discovered, and by another the very slight lengthening of the day in the lapse of many ages.

A dome of moderate thickness may be treated as to its mass and the centre of gravity of its parts as a hemispherical surface of the mean radius between the outside and inside multiplied by the thickness $2t$, or t on each side of the mean surface. I need not prove here that the mass of a thick hemispherical dome of outer radius $a+t$ and inner radius $a-t$ is $\frac{2\pi}{3}\left\{(a+t)^3-(a-t)^3\right\}$ $=4\pi a^2 t\left(1+\frac{t^2}{3a^2}\right)$. If $\frac{t^2}{3a^2}$ is small enough to be neglected this $=4\pi t a^2$, the surface of the hemisphere of radius $a\times 2t$. We shall save a great deal of writing if we make the mean radius a our unit of length or 1, and then t is a fraction of a which will never be so much as $\cdot 1\,a$ and generally much less, and all the sines and cosines will be x and y. We may also make $4\pi a^2 t$ or M our unit of mass. And further, as a narrow lune is the 'element' of a hemisphere, or a hemisphere is composed of a great number of narrow lunes, all our results will be the same whether we deal with $a\beta$ the width of a narrow lune at its base, or with $2\pi a$ the whole circumference; and we need not trouble ourselves about the actual width, or the value of the angle β, remembering that our elementary lune has no sensible horizontal curvature to help its stability. Therefore all the figures indicating weights and pressures will come out in decimals which are fractions of M, which we may consider either a lune or a dome as we please. By the word dome alone I shall always mean a hemispherical one unless some other is indicated.

I just say one word to warn non-mathematical readers against the not uncommon mistake of

taking a round arch for the element of a dome, or fancying that an arch may be used as a model to find domal results. A dome cannot be made up of any number of equal arches, but it is made up of strips nearly triangular, but with slightly convex sides, running rapidly to o at the top. And that is the reason why a dome is so much more stable, or requires so much less thickness* than a barrel vault, which *is* composed of arches. Nevertheless a dome is 'generated' (as mathematicians say) by a revolution of a quadrant or arch about one side; but that means that a single principal section of the dome is the same as a section of the arch: an 'element' is the thing contained between two adjacent principal sections or sections through the axis of a body of a revolution.

All through this paper I shall keep to the following notation: ϕ is the upper arc from A, the top of the quadrant, to whatever variable place we are dealing with; ϕ' to any which is fixed for the time: x and y are the corresponding horizontal and vertical ordinates; and as we have made the radius 1, all the x's and y's will be sines and cosines of ϕ. The lower arc from B or $90° - \phi$ will be always called ψ, of which x and y will be cosine and sine. As usual, $\bar{x}$ is the distance of the centre of gravity from the vertical axis, and $\bar{y}$ from the horizontal, but we shall have very little to do with $\bar{y}$. It will be convenient to use $\bar{z}$ for the $\bar{x}$ of lower arcs to distinguish them, and $\underline{x}$ for a middle arc. We must find these at once for any piece of a lune, and also its weight. In this figure E D B is not a straight line necessarily.



By the general property of the circle, and because the width and the weight of each horizontal element $x\,ds$ of a lune (s being $a\varphi$) varies as x, the weight of a piece ϕ, or

$$W = \int x\,ds = \int \frac{x\,dx}{\sqrt{1-x^2}} = C - \sqrt{1-x^2} = C - y.$$

The limits of integration are from y to 1 for ϕ: from o to y for ψ, and from y to y' for a middle arc. $\therefore$ W of $\phi = 1 - y$; W′ of $\psi = y$; and $\underline{W}$ of a middle arc $= y - y'$. In other words, the weight of every piece of lune, and $\therefore$ of every zone of a dome, is measured by its vertical height; and the whole dome or lune = the same height of a cylinder or strip of cylinder on the same base; from which it follows without any more calculation that $\bar{y} = \frac{y}{2}$. But $\bar{x}$ is not so simple, and we must now find that by the usual process:

$$W\bar{x} = \int \frac{x^2\,dx}{\sqrt{1-x^2}} = C + \frac{\sin^{-1}x - x\sqrt{1-x^2}}{2} = C + \frac{\varphi - xy}{2}$$

and taking the limits from o to x for ϕ, and x to 1 for ψ,

$$\bar{x} = \frac{\phi - xy}{2(1-y)}; \quad \bar{z} = \frac{\psi + xy}{2y}; \quad \underline{x} = \frac{\varphi' - \varphi + xy - x'y'}{2(y-y')} = \frac{'\bar{x}\,(1-y') - x\,(1-y)}{2(y-y')};$$

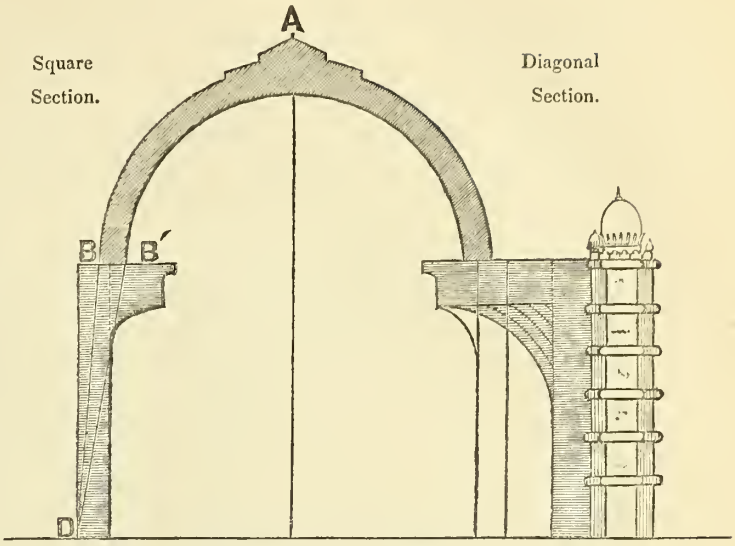
which last is the most convenient form, as I shall give a number of $\bar{x}$'s and $(1-y)$'s in the table, from which $\underline{x}$ may easily be got. $1-y$ is of course v. sin ϕ. I give also such other arcs and their natural functions as we shall want, as they are difficult to find in books.

The next thing we shall want is the horizontal thrust at the top or bottom of any piece of

From top ϕ		V. s. ϕ $1-y$	Cot ϕ $\frac{y}{x}$	Sin cos xy	Cos ϕ y	Sin ϕ x	x of c.g. $-\bar{x}=$	R	T	$\breve{T}$	P+Q	Of lower Arc $\bar{z}$	Ψ
5° =	0873	004	11·43	087	996	087	..	..	..	of	..	797	85°
10	1745	015	5·66	171	985	174	..	..	..	tapered	210	..	80
12	210	022	4·7	203	978	207	16	047	098	dome, p. 15.	..	..	78
18	314	049	3·08	294	951	309	204	105	151		..	..	72
20	349	06	2·75	321	94	342	233	109	165	085	222	817	70
22	384	073	2·47	347	927	375	253	122	173	..	..	..	68
25	437	094	2·14	383	906	423	29	133	202	..	..	..	65
30	523	134	1·73	433	866	5	336	164	232	124	22	855	60
36	628	192	1·38	475	809	588	4	188	264	145	..	..	54
40	698	234	1·19	492	766	643	432	203	277	154	..	881	50
42	733	257	1·11	497	743	669	462	207	285	..	..	..	48
45	785	293	1·	5	707	707	486	221	293	168	212	925	45
50	875	357	·839	492	643	766	536	230	299	177	208	..	40
52	908	384	781	485	616	788	551	237	3	..	..	..	38
54	942	412	726	475	588	809	567	242	298	179	194	938	36
58	1·012	470	625	449	53	848	6	248	293	181	186	95	32
60	1·047	5	577	433	5	866	614	252	288	180	180	956	30
62	1·082	53	532	414	466	882	630	253	282	..	174	962	28
64	1·117	561	488	394	438	899	644	254	274	..	165	968	26
66	1·153	593	445	371	407	913	658	255	264	..	156	972	24
68	1·186	625	404	347	375	927	671	256	252	165	145	976	22
70	1·222	658	364	321	342	94	685	255	238	..	138	98	20
71	1·239	674	344	308	325	945	691	254	232	..	135	981	19
72	1·256	69	324	294	309	951	697	253	223	15	129	983	18
74	1·291	724	287	265	276	961	709	252	2	..	121	987	16
76	1·326	758	249	235	242	97	719	251	190	14	107	989	14
78	1·361	793	212	203	207	978	728	250	168	..	..	991	12
80	1·396	826	176	170	174	985	743	242	145	..	087	994	10
90	1·571	1·	0	0	0	1·	785	215	0	0	0	1·	0

All are decimals unless otherwise indicated.

For Middle Arcs.	$\bar{x}$	Secant	
52° to 18°	·60	8°	1·01
20	·61	9	1·012
22	·62	10	1·0154
		11	1·0187
70 to 20	·723	12	1·0223
22	·76	13	1·0263
30	·778	14	1·0306
80 to 60	·94	15	1·0352
64	·947	16	1·04
66	·95	17	1·0456
68	·97	18	1·05
70	·974	20	1·064



Gol Gomuz, $\frac{1}{8}$ in. to 10 feet.

lune due to its own weight only, assuming it be stiff enough not to break anywhere exeept at the point then in question. For ϕ we will call this R, and P for ψ; and R will always be used for the thrust outwards at the bottom of ϕ, when stiff enough to be taken as one picee, and P for the pressure inwards at the top of ψ due to its own weight, the lune being tied at the bottom and balaneed at the top by the opposite lune of the pair. Then

$$R = \frac{W(x-\bar{x})}{1-y} = x-\bar{x}\,;\ \text{and}\ P = 1-\bar{z}$$

When we have got a dome which we know anyhow to be thick enough to stand without any ties above the bottom, and yet not very thick, we ean now easily ealculate the tension or thrust there—or rather what it would be if it had a great many vertical craeks right through it. It is plainly this R at the bottom, or $1-\bar{x}$, whieh is there ·215, *i.e.*, rather more than a fifth of the whole weight; or the dome would stand upon a conical drum sloping 1 to 5, independently of the drum's own weight, whieh would help it to do with rather less slope. But the thickness, if more than enough for mere stability, also affeets R thus: if the dome or a pair of stiff lunes stood upon a smooth plate, they would slide away on their inner edges at the bottom, and turn upon their outer edge at the top, or somewhere near it; and therefore the angle of pressure is the inclination of the line joining those points. Consequently $R = ·215\,\frac{1-t}{1+t} = ·215(1-2t)$ very nearly, as t is so small that we may neglect t^2 in all the domes we shall have to deal with.

But for very thick domes like the Gol Gomuz this is too mueh, beeause t^2 is not very small, and because we have assumed that the e. g. of the thiek lune is no farther from the axis than the e. g. of a very thin lune at the mean distanee, whieh is not so: *i.e.* $\bar{x}$ is then sensibly $> ·785$, the $\bar{x}$ for the mean surfaee. Moreover the weight is then eonsiderably $>$ the mean surfaee $\times$ thiekness. If r is the inner radius and r_1 the outer, $M\bar{x}$ for the whole quadrant $= ·785\int_r^{r_1} r^3\,dr$ (omitting the eommon quantity β or 2π) $= ·785\left(\frac{r_1^4-r^4}{4}\right)$, and $M = \frac{r_1^3-r^3}{3}$: $\therefore \bar{x} = \frac{3}{4}\cdot 785\,\frac{r_1^4-r^4}{r_1^3-r^3}$, and

$\frac{R}{M} = \frac{r-x}{r_1} = \frac{r}{r_1} - \frac{\cdot588}{r_1}\frac{r_1^4 - r^4}{r_1^3 - r^3}$. In the Gol Gomuz $r = 68\frac{1}{2}$ feet, and $r_1 = 78\frac{1}{2}$, which are nearly as 7 to 8 with a mean radius $7\cdot5$ $\therefore \bar{x} = 6\cdot17$; while calculated from the mean radius it would be $7\cdot5 \times \cdot785 = 5\cdot88$. And $\frac{R}{M} = \frac{\cdot83}{8}$ or nearly $\cdot1$, while calculated by the other method, which is right enough for thin domes, it would be $\cdot215 \times \frac{7}{8} = \cdot188$; a very wide difference, which increases rapidly with the thickness.

Therefore the drum which is to carry such a dome without any tie need only contain a slope of $\tan^{-1}\cdot1$ or about 6°, the slope of a rather sharp spire: *i.e.* a line from B the outer edge of the dome to D the outer edge of the base of the drum ought to have that slope, subject to a little gradual diminution downwards if we take the weight of the drum itself into account, but that is very little indeed upon such a small inclination. Such a line is not contained in the walls of the Gol Gomuz at the middle of each side of the square, and if the dome itself were not three times as thick as it need be the fabric would not be quite stable at those four points. But by reason of the vaulting under the gallery beneath the dome the line of pressure may be considered to go from the inside of the dome B′ to the outside of the base of the drum, and the dome itself is much more than stable upon lines of pressure from B′ to A. Besides that, the corners of the square drum increase its power of abutment enormously; and although it would be barely stable if the drum were round or as close to the dome all round as it is at the four nearest points, it is abundantly stable on the whole. The above figure is alone sufficient to show the superabundant stability conferred by the diagonal abutments, to say nothing of the turrets beyond them.

If a thin lune had no tendency to break inwards below the top, as we shall find that a round arch has not, we might take R throughout as the thrust outwards, and the condition of stability would simply be that the resultant of R and W must not go beyond the tangent at ϕ downward: or R must be $< W \cot\phi$, or $x - \bar{x} < (1-y)\frac{y}{x}$. You will easily find from the table, which gives R for many places, that this holds good down to $67\frac{1}{2}°$, or say 68°, as we need not trouble ourselves with minute divisions: at which place also R is a maximum. But the upper part of a lune *will* fall in unless it has sufficient thickness, though a dome can not, except at the top; and that prevents us from treating the lune as stiff and using R at once, and we must proceed in another way.

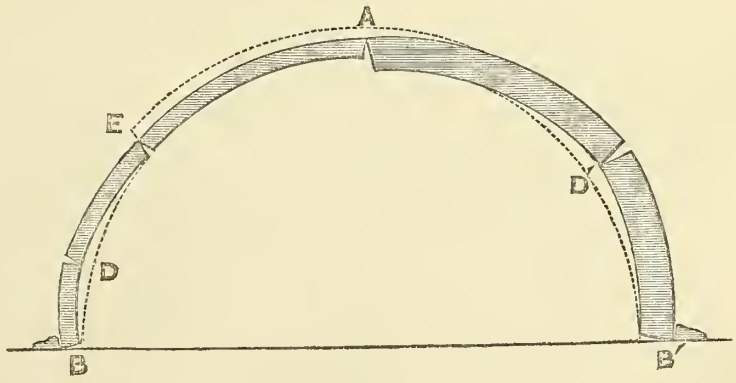
All the pressure which each lune exerts upon its neighbours down to a certain point which we shall find presently, goes to increase its thrust below that point, just as much as if the thrust above were borne by horizontal struts from each lune to the opposite one; for every leaning beam pushes outwards at the bottom just as much as inwards at the top.

Let us begin with any little cap or segment so small that it may be treated as a solid piece, and let it rest all round on infinitely small bits or elements of the arc which would each be mathematically called $a\,d\phi$, or $d\phi$ as we make $a = 1$, and which $\therefore$ coincide with the tangent of the circle here. If W is the weight of the cap, the horizontal thrust T at the bottom of $d\phi$ is evidently W cot ϕ or $(1-y)\frac{y}{x}$. And so long as this keeps increasing with ϕ the dome will be stable down to ϕ; for there is necessarily the same horizontal force inwards at the top of $d\phi$ as at the bottom, *i.e.* the pressure inwards due to the dead weight on the top of $d\phi$ is greater than the pressure outwards at the bottom of the next preceding $d\phi$ or at ϕ. But as soon as T at any $\phi + d\phi$ is less than it was at ϕ the outward pressure prevails; for though the weight $(1-y)$ increases, the inclination of the tangent $\frac{y}{x}$ diminishes as we go downwards.

You may see by the table that $(1-y)\frac{y}{x}$ reaches its maximum of ·3003 at 52°, which is considerably greater than R: ∴ a dome is stable down to 52° independently of thickness, but has a thrust there much greater than if it were thick enough to stand as a pair of lunes. This is the same conclusion as is arrived at with much more elaborate mathematics in the 'Encyclopædia Britannica,' and elsewhere; and this is the point at which that and other treatises on domes stop; except that the author then jumped to the prodigious conclusion that below 52° a hemispherical dome will not stand without tying, but should turn outwards with contrary flexure or an ogee curve, which he was pleased also to call a Gothic dome. Those who compare this with Mr. Tarn's paper may observe that he treats a pair of lunes as thick enough not to fall inwards except at the top; which is true in fact of such thick hemispherical domes as he deals with, but is not true of domes only just thick enough to be stable (as we shall find presently), and must not be assumed *à priori* of any dome. We shall find that it is far from being true of either tapered domes or pointed ones, which will bear being much thinner than uniform hemispherical ones.

It is so important to understand this distinction that I add this simple proof of it. If we used R for the thrust outwards at any place where T is > R, we should have this absurd result, that tying the dome increases the thrust immediately below the tie; for T represents that thrust: or you may consider it to represent the bursting force of so much of the dome as will hold together, or is tied, acting as a wedge upon the parts below. Below the place where the natural stability ends, T has no meaning, except that it would be the wedge-like force of the dome on the parts below, if it were tied there. But if the thickness is enough to keep a pair of lunes from falling inwards anywhere, then R may be used, modified by the thickness, as we shall see presently. From this we learn also that putting in hoop iron above 52° would be of no use whatever, as all the pressure is already inwards when the dome is held fast by sufficient pressure from below, which has to be just as great whether it is tied above 52° or not. In all this a dome differs entirely from a round arch.

How then will a dome begin to break if it is too thin for a pair of lunes to be stable inwards near the top? Everybody knows that it will burst somewhere about 20° from the bottom; but where will it begin to open above? Not at the top, because somewhere about 20° from the top (as we shall find) a pair of thin lunes tied at 52° would fall inwards; and as they cannot fall in when combined in a dome, a certain segment of dome, varying with the thickness, will hold together and descend as one piece, down to E in the left side of this figure (or ϕ' from A), and there each lune will begin to open outwards, turning on the outer surface as a hinge, just as if it were falling inwards at E. At D (ϕ) another hinge will be formed the other way, and the lower piece BD will turn on its outer edge at B. The right side of the figure shows how a round arch or a pair of *thick* lunes would break if they were too much loaded at the top. What we have to do is to find such a value of t as will shift the breaking point enough to make the inward horizontal forces just exceed



the outer ones everywhere, *i.e.* to find the maximum t required to keep the piece BD from being pushed over by ED, whatever ϕ and ϕ' are.

We will take first the force transmitted to ϕ from the weight $(1-y')$ of the piece which does not break, and that produces a thrust $\dot{S} = (1-y')\frac{x-x'}{y'-y}$. (The forces indicated by letters with spots or other marks are always those without t, and $\underline{R}\,\dot{P}\,\dot{Q}$ are those of the table.) The next is $\underline{R}=x-\underline{x}$ due to the weight of the middle piece $\phi-\phi'$, for which $\underline{x}$ the formula was given at p. 3. Then there is $\dot{P}=1-\bar{z}$ due to the weight of the lower piece ψ leaning inwards; and lastly, $\dot{Q}$ due to the weight of all above ϕ (*i.e.* $1-y$) pressing the lower piece inwards, and $\dot{Q}=\frac{(1-y)(1-x)}{y}$. But when we take into account the shifting of the breaking points alternately to the inner and outer surfaces by t sin ϕ or tx horizontally and ty vertically, the equations assume a more complicated form as follows:—

$$R+S=\frac{(y'-y)(x-\underline{x}-tx)+(1-y')(x-x'-tx-tx')}{y'-y+ty'+ty}$$

Since t is small we may always multiply by $1\pm mt$ instead of dividing by $1\mp mt$, which is equivalent to neglecting t^2 and higher powers of t, m being any coefficient.

$$\therefore R+S=\left\{\underline{R}-tx+\frac{1-y'}{y'-y}\left(x-x'-t\overline{x+x'}\right)\right\}\left(1-t\frac{y'+y}{y'-y}\right)$$

$$=\underline{R}+\dot{S}-t\left\{x+\frac{1-y'}{y'-y}(x+x')+(x-x')\frac{y'+y}{y'-y}\cdot\frac{1-y'}{y'-y}+\underline{R}\frac{y'+y}{y'-y}\right\}$$

$$P=\frac{y(1-\bar{z}+t)}{y-ty}=(1-\bar{z}+t)(1+t)=\dot{P}+t(2-\bar{z}):$$

$$Q=\frac{(1-y)(1-x+t+tx)}{y-ty}=\frac{1-y}{y}(1-x+\overline{1+x})(1+t)=\dot{Q}+2t\frac{1-y}{y}$$

$$\therefore\ P+Q=\dot{P}+\dot{Q}+t\left(\frac{2}{y}-\bar{z}\right)$$

and combining them all we must have for stability—

$$t\left\{x-\bar{z}+\frac{2}{y}+\underline{R}\frac{y'+y}{y'-y}+\frac{1-y'}{y'-y}\left(x+x'+(x-x')\frac{y'+y}{y'-y}\right)\right\}>\underline{R}+\dot{S}-\dot{P}-\dot{Q}$$

It is impossible to solve such an equation as this: much more to find a maximum of t from it. We can only proceed tentatively, and I find that taking ϕ' anywhere from 20° to 30°, and ϕ from 70° to 72° (the two first giving apparently the maximum) we get something very near the proportion of $7t>\cdot154$, or $t>\cdot022$; and therefore we may safely say that a dome 100 feet wide and 27 inches thick will be stable—tied of course at the bottom.

But this is a kind of calculation which I confess I have not patience to extend to the still more complicated cases which we ought to investigate, and fortunately we can arrive at substantially the same result more easily by several modes of approximation with only insignificant errors, and those always on the safe side.

The easiest approximation is this. The natural stability will evidently go not only to 52°, but to wherever the tangent of the inner semicircle at 52° runs out of the dome. If we try $t=\cdot021$

(which we now know is not quite enough), the tangent will run out a little below 68°, because sec. 16°=1·04; *i.e.* the upper 68° may then be treated as a solid wedge forcing open the lower 22°, and having to be resisted by the forces which we called P and Q with their points of action shifted inwards at 68°, and outwards at 90° by t, as explained before. At 68° T=·252, for we may consider the dome held there by the inside as well as the outside, and so take the $\frac{y}{x}$ due to the tangent there. P+Q=·145; and $t\left(\frac{2}{y}-\bar{z}\right)=4{\cdot}357\,t$, which must ∴ >·107, or t >·0245: *i.e.* we find thus (what we know also from the other calculation) that we assumed too little for t. The average between the assumed ·021 and this ·0245 is nearly ·023; and thus either calculation gives substantially the same result, and this rather the greatest or safest. The reason why it is so is that we now take no benefit of t at whatever would be the upper breaking place, for the dome would not really remain solid down to 68° but open somewhere above. We have not yet proved that the ·023 is enough for all places below 68°, and if we were using this method only we must try other places; but it is not necessary in this case, as we already know that ·023 is more than enough below 68°.

It must be understood that this analogy to the action of a wedge is not really true, for it assumes what never happened in any arch or dome in the world with radial courses, that they can slide on each other. If they could you may easily see by the table that T would prevail over P+Q far too much to be helped by t, above 68°, and even above 52°. Nor is it strictly correct to say that P+Q acting on the inside at D (fig. p. 3) is equivalent to a prop parallel to B D acting at the outside. In short this is only an approximate mode of evading a much more troublesome calculation.

Another mode of approximation is to find first what thickness will keep a pair of lunes stable *inwards* from o to 52° and then see if that is enough below. The calculation for that is easy. The opening point or hinge is now transferred to the inside of the dome at o°, or lowered by t, and to the outside at ϕ which is somewhere near 20°, and P+Q now has to be taken for a middle arc, $\underline{\mathrm{P}}$ being $x'-\underline{x}$, and you will find the requisite $\underline{x}$'s in the table. Then $x'\,y'$ being those of 52°, the equations will be as follows:

$$\mathrm{R}=\frac{(1-y\,(x-\bar{x}+tx)}{1-y-t\,(1+y)}=(x-\bar{x}+tx)\left(1+t\frac{1+y}{1-y}\right)=\underset{\cdot}{\mathrm{R}}+t\left(x+\underset{\cdot}{\mathrm{R}}\frac{1+y}{1-y}\right)$$

$$\mathrm{P}=(x'-\underline{x}-tx')\left(1-t\frac{y+y'}{y-y'}\right)=\underline{\mathrm{P}}-t\left(x'+\underline{\mathrm{P}}\frac{y+y'}{y-y'}\right)$$

$$\mathrm{Q}=\frac{1-y}{y-y'}\left(x'-x-t\,\overline{x+x'}\right)\left(1-t\frac{y+y'}{y-y'}\right)=\mathrm{Q}-t\,\underline{\mathrm{Q}}\left(\frac{x'+x}{x'-x}+\frac{y+y'}{y-y'}\right)$$

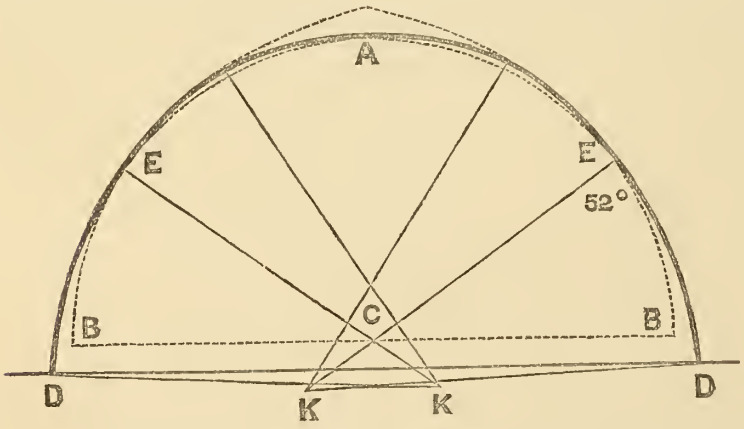
At 20° this makes P + Q = ·256 − 2·196 t
R = ·109 + 3·862 t

∴ for exact stability o = ·147 − 6·058 t; ∴ t must > ·0245; and if you try at 22° and 18° you will find that this is the maximum. We already know that this is more than enough for stability outwards below 52°, or we may say below 68° at once; for if a lune is stable inwards we have nothing to do with T, and may use R throughout, and R increases and is <W cot ϕ down to 68°. And if we use R in the same way below 68°, reversing the signs of t and taking P and Q from 90° instead of 52°, we shall get this equation of stability: $t\left(\frac{2}{y}-\bar{z}+x+\underset{\cdot}{\mathrm{R}}\frac{1+y}{1-y}\right)>\underset{\cdot}{\mathrm{R}}-\underset{\cdot}{\mathrm{P}}-\underset{\cdot}{\mathrm{Q}}$;

which at 70° (the maximum of t for this formula) makes $6{\cdot}3\ t > {\cdot}12$ or $t > {\cdot}019$; and the mean between this and ·0245 is again very nearly the original ·022. So that we shall be safe in using whichever of the various approximations is most convenient in each case, but that with T is the safest, and the easiest for calculation.

Since the thickness $2t = {\cdot}044a$ $\therefore$ $2a$ the mean diameter $= 45 \times$ thickness; and $2a + 2t$ the outside diameter $= 46 \times$ thickness, and $2a - 2t$ the inside diameter $= 44 \times$ thickness. It is also worth notice that R − P − Q without $t = \dfrac{\mathrm{R} - {\cdot}215}{y}$; $\therefore$ $\mathrm{P}+\mathrm{Q} = \dfrac{{\cdot}215 - \mathrm{R}\,(1-y)}{y}$. For $(\mathrm{R}-\mathrm{P}-\mathrm{Q})y$ $= \bar{z}\,y - \bar{x}\,y - 1$, which you will find $= x - \bar{x} - {\cdot}215$ if you substitute the values for $\bar{z}\,y - \bar{x}\,y$ and put ·785 for 45°. In like manner in a dome tied at ϕ' (below 68°) $\mathrm{R}-\underline{\mathrm{P}}-\underline{\mathrm{Q}} = \dfrac{\mathrm{R}-\mathrm{R}'}{y-y'}$, R′ being the R of the table at ϕ'.

We can now also see approximately how much a dome of no sensible thickness must deviate from a hemisphere to make it stable. Down to 52° the hemisphere will do. Indeed a rather flatter segment would be stable and give rather less thrust at 52°, but that is not worth considering if we want the dome to be as near a hemisphere as possible. At 52° it must begin to spread until the radius is lengthened ·04 at 68°, which carries the natural stability down to there. The effect of the thickness below that was to shift the points of pressure ·022 inwards at 68°, and ·022 outwards at 90°. But this ·062 at 68° measured horizontally is $\cdot 062x = {\cdot}0575$; and $\therefore$ the whole horizontal spread at the base is very nearly ·08. Then in order to keep the height of the dome = half its width, the floor must be let down this same ·08, a twenty-fifth of the diameter, below the centre C, making the lower part part of a slightly pointed dome. *A fortiori* a dome of this shape and any moderate thickness would be still more stable; and I am inclined to think it looks better than a hemisphere, as may be expected, for that which is mechanically right generally satisfies the eye. Though the difference of shape is hardly visible on a small scale, I give a sketch of it to show the mode of construction: the centres K K of the lower arcs may easily be found by trial, or by joining D E and drawing a ⊥ from the middle of D E to cut E C prolonged in K.



This approximation remarkably agrees with the much more difficult direct solution of the problem, of which the result is given in the 'Encyclopædia Britannica' under the article 'Arch.' The table of ordinates of the curve there given is inconvenient for comparison with a hemisphere, and therefore I have transformed them as follows, so as to make y and x the vertical and horizontal ordinates of a dome of equilibrium as high as half its width, which I also make 1000 instead of 1313 as that table makes it. The result is that $\sqrt{x^2+y^2}$ or r of the curve exceeds a of the hemisphere which coincides with it near the middle by $\cdot 043\,a$ at 23° and falls short of it by $\cdot 041a$ at 73° taking y for $\cos\phi$ in the upper half and x for $\sin\phi$ in the lower.

y	x	ϕ	$\sqrt{x^2+y^2}$	Δ
997	152	4	1006	$+\cdot 006\,a$
980	305	12°	1026	·026
930	457	21°	1036	·036
918	495	23°	1043	·043
888	533	28°	1036	·036
831	610	34°	1020	·020
751	685	41°	1016	·016
646	762	50°	999	—·001
535	823	56°	982	·018
433	868	60°	970	·030
313	912	66°	963	·037
162	959	73°	959	·041
81	980	81°	983	·027
0	1000	90	1000	·0

There are plenty of other curves between a hemisphere and a cone which will make stable domes. The only condition to be satisfied is that T or $W\frac{dx}{dy}$ shall increase downwards throughout, as it does very strongly in a cone, where $\frac{dx}{dy}$ is constant and W increases rapidly. The greater the stability of the dome, apart from thickness, the greater T is, or the thrust at the bottom. A dome of catenary section would be amply stable, because a catenary is well known to be the curve which makes a just stable arch, and as the dome generated by its revolution gains much more weight in the lower than the upper parts it must be very stable. The best way of drawing a catenary is to hang a thin chain of very loose links against an upright board and trace it with a pencil: it is an unpleasant curve to deal with mathematically, and a dome of no thickness and exact equilibrium throughout is an aggravated catenary, for the weight of each element is also unknown *à priori:* all we know is that the weight of each ring varies as x. It is evident that no dome without thickness can spring vertically, *i.e.* the centres of curvature KK must be below the floor DD. If m is half the latus rectum of an upright paraboloid, and x the horizontal ordinates, $T = \frac{m^3}{3x}\left(1+\frac{x^2}{m^2}\right)^{\frac{3}{2}}$ which increases from where $\frac{x}{m} = \sqrt{2}$; or the whole of a paraboloid would make a stable dome infinitely thin, except a little bit near the top which requires some thickness; and the tangent continually approaches verticality but never reaches it.

We may now measure the strength of the tie required at the bottom of a dome when the thickness is enough to make a pair of lunes stable both inwards and outwards, so that we may take R as the thrust anywhere. We know that $t = \cdot 025$ does so. When we come to thinner domes we shall have to deal differently with R. But, as I said before of the thick Indian domes, the actual thrust at the bottom is $\cdot 215\,\frac{1-t}{1+t} = \cdot 215 \times \cdot 95 = \cdot 203$. A dome 100 feet wide and 1 foot thick will

weigh about 1000 tons, and ∴ $2\frac{1}{2}$ feet thick will weigh 2500 tons, and R will be a little more than 500 tons; or the bands round the bottom must be able to bear that weight, which would require ten iron bands of rather more than two square inches in section, according to the usual reckoning of strength, or hoop iron amounting to twenty square inches in section altogether. If these bands are spread over a few feet above the bottom of the dome its stability will be immensely increased, or much less thickness will do, and ∴ fewer or smaller ties. For suppose the highest tie to be at D (φ') in the figure at p. 3, you see that the line of pressure leans more within the same thickness, and that is the way that thickness gives stability. Moreover, the vertical height of that line is now increased by ty' at the lower end as well as by ty at the upper. Let us call the new P and Q from φ' $\underline{\mathrm{P}}$ and $\underline{\mathrm{Q}}$, as we call the $\bar{x}$ for a middle arc $\underline{x}$, which we find by the formula at p. 3. I have also given in the table several $\underline{x}$'s, from 80° to a few places about 68°, and others may easily be interpolated. Then we shall have

$$\mathrm{P} = \frac{(y-y')(x'-\underline{x}+tx')}{y-y'-t(y'+y)} = (x'-\underline{x}+tx')\left(1+t\frac{y+y'}{y-y'}\right)$$

$$= \underline{\mathrm{P}} + t\left(x' + \mathrm{P}\frac{y+y'}{y-y}\right);\ \mathrm{P} \text{ being } x'-\underline{x}$$

$$\mathrm{Q} = \frac{(1-y)(x'-x+t\overline{x+x'})}{y-y'-t(y'+y)} = \frac{1-y}{y-y'}(x'-x+t\overline{x+x'})\left(1+t\frac{y+y'}{y-y}\right)$$

$$= \underline{\mathrm{Q}} + t\underline{\mathrm{Q}}\left\{\frac{x'+x}{x'-x} + \frac{y+y'}{y-y'}\right\};\ \underline{\mathrm{Q}} \text{ being } \frac{1-y}{y-y'}(x'-x)$$

Now let us try a thickness $2t = \cdot025$ (about half the former amount) which will carry the natural stability past 64°, since sec 12° = 1·022; and there T = ·274, $\underline{\mathrm{P}}$ = ·038, and $\underline{\mathrm{Q}}$ = ·186 ∴ T − $\underline{\mathrm{P}}$ − $\underline{\mathrm{Q}}$ = ·053. The coefficient of t in the above formulæ for P + Q is now

$$x' + \frac{1-y}{y-y'}(x'-x) + \frac{y+y'}{y-y'}(\underline{\mathrm{P}}+\underline{\mathrm{Q}}) \text{ which } = 5\cdot48 \text{ at } 64°;$$

∴ t need only be ·01, which is rather less than we assumed. But we do not know that 64° is the weakest place or requires the greatest value of t: and in fact it is not; but 68°, or something very near it, is. But what is the force to be used for T below the limits of natural stability, where T ceases to have any meaning? We must add to it the $\underline{\mathrm{R}}$ due to the little bit from 64° to φ, the place which we are going to try, which is now 68°. In short pieces near the bottom $\underline{\mathrm{R}}$ or $x - \underline{x}$ sensibly $= \frac{x-x_1}{2}$ (x_1 being at the higher place), and here $\underline{\mathrm{R}}$ = ·014. So we must now have P + Q with t > T + $\underline{\mathrm{R}}$ or ·288. $\underline{\mathrm{P}}$ = ·015, $\underline{\mathrm{Q}}$ = ·181, and the t terms = 7·57t, which must ∴ > ·092; or t must be > ·0122, which is very nearly what we took for trial. So we have this practical result, that carrying the bands up 10° from the bottom, or about $8\frac{1}{2}$ feet in a dome 100 feet wide, enables us to reduce the thickness nearly half; or such a dome need be only 1·22 feet or 15 inches thick.

The tie at 80°, or practically the sum of all the ties near 80°, must = the ·288, which is the amount of P + Q at the top of their piece of 10° and ∴ also at the bottom, except that they may be reduced by the P + Q from 90° to 80°, which helps the tie at 80°, and which = ·08 omitting the modification by t; so that it comes to nearly the same as the tie required at the bottom if there is only one there; but then it is ·208 of a dome of little more than half the weight of the former one. If the dome tied at 80° were still made ·05 thick it would only want a tie there = $\underline{\mathrm{R}}$ − $\underline{\mathrm{P}}$ − $\underline{\mathrm{Q}}$ = ·162

of its weight. And it will require no tie at all below 80° if a vertical line from the outside there falls within the thickness at 90°, or if $x' + t > 1 - t$, which it is if $2t > \cdot 015$ as it must be for stability above 80°.

All these calculations assume that the stones are strong enough not to crush at the edges, and are or act as *throughs*, at least in the weak part of the dome. On the other hand I take no account of the enormous advantage of the natural tenacity of the masonry, but assume the dome to be split up into any number of lunes without any bonding. Compression does not require providing for by any such margin of strength as tension, which is always precarious, and therefore I have no doubt that these results are practically as well as theoretically safe in well-built domes, though of course one would not run the calculation so close in practice, and would introduce hoop iron. The inner dome of St. Paul's is only 18 in. thick, which is less than our calculation gives for an hemisphere; but it is less than an hemisphere, and the lower part is much thicker and imbedded in the cone, and probably quite equivalent to a dome tied at 80°.

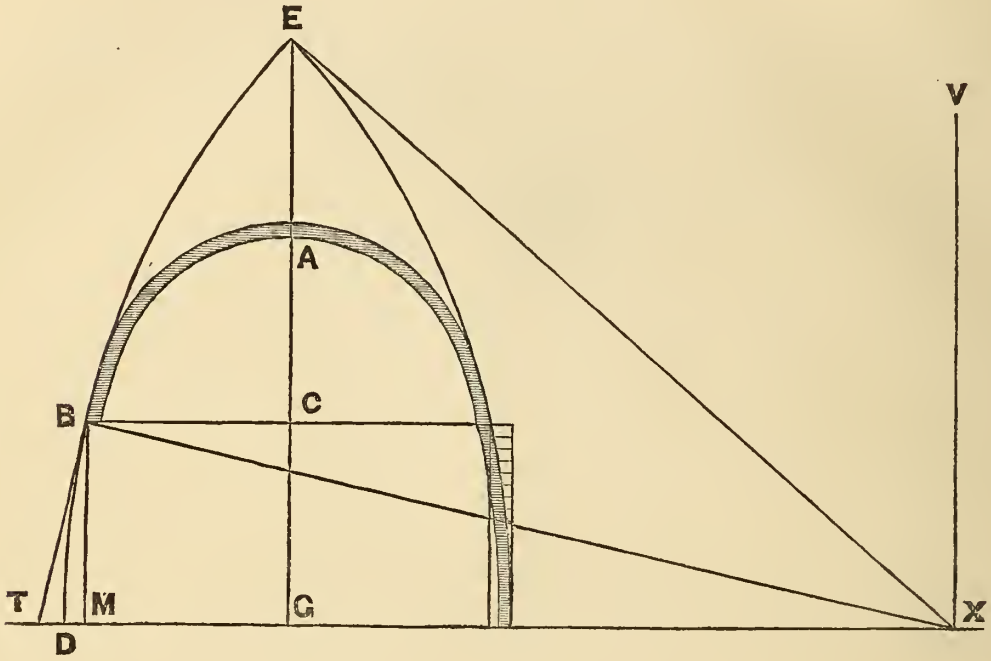
There seems to have been a notion in all ages that fabrics of this kind, even including arches, are more stable if the courses or beds are horizontal. One of the earliest domes in the world, the Tomb of Agamemnon at Mycenæ (see Fergusson's Handbook, p. 257), necessarily a pointed one, is so built; and I was much interested at finding in Mr. Donaldson's section of it made by himself, that so far from this dome keeping its shape unusually well it has kept it unusually ill, and the stones have actually slid over each other and project inwards in a very irregular way. The truth is that the lower courses of a dome ought to be not less but more inclined than the radial direction: for otherwise the enormous outward thrust just above the tie or abutment at the bottom would perhaps be enough to make them slide over any cement, unless they are also joggled, or what is still better, have a linked iron rod or chain embedded in some of the lower courses, so that its extension in hot weather may not split the dome. Acute angles in stone are very weak, which would be involved in making the inclination more than radial: if they are used the dome ought to be thick enough to keep the line of pressure everywhere clear of those angles.

I suppose that same erroneous idea of the superior stability of horizontal beds is at the bottom of the practice of building spires with the beds horizontal instead of square to the face. They are far more stable square, for in that case each piece of spire lies in a kind of polygonal cup and would stand a considerable shake without being displaced or twisted, as the tops of spires sometimes are in a mysterious way by the wind. I have had all the spires so built over which I have had any control, and the builders say that on the whole they take no more trouble, though the corner-stones alone do. The objection that damp would run in seems to me immaterial in a spire: and I have heard no complaints of it, even in a very stormy place.

But a stable dome requires no tying at all if it rests on a *drum* which contains a cone with a slope coinciding with the resultant of R and M at the bottom of the dome, which we may call ·2 or tan 12°. And that would be true if the drum itself had no weight: but it has; and its own weight leaning inwards enables it to act like the lower part of another dome, and ∴ its slope may gradually diminish downwards, and it may even become vertical at the bottom with only the same thickness as the dome above.

In this figure (next page) B T is the tangent to the initial slope of the curved drum B D; and B M being vertical M B T = 12° = M X B. V X is also vertical. The circle B D with radius B X is continued upwards till it cuts the prolonged axis of the dome at E. In other words this drum is the lower 12° of a pointed dome much taller than hemisphere, of which we have first to find the radius of curvature B X or r. Let the height of the drum be h: then $r = \frac{h}{\sin 12°}$

$= 4{\cdot}8\ h$. For simplicity let $h = a$. Then $GX = r \cos 12° - a = r\ (\cos 12° - \sin 12°)$, and also $= r \sin EXV = r \sin \varphi'$ of the pointed dome (φ' being reckoned from XV as before) $\therefore \sin \varphi' = \cos 12° - \sin 12° = {\cdot}771 = \sin 50°$ nearly, or $\varphi' = 50°$. $\therefore GE = r \cos 50° = 4{\cdot}8\ a \times {\cdot}643$



$= 3{\cdot}1\ a$; or the pointed dome goes twice as high as the dome itself above the floor of the dome and is a great deal heavier. In such an extreme case as this we may conclude without the calculation which we shall make when we come to pointed domes, that if that drum will bear its own continuation as a pointed dome it will bear the much lighter hemisphere; and we shall find too that pointed domes will do with much less thickness than hemispheres of the same width. So that the hemisphere may stand safely upon the convex drum B D instead of the cone B T which spreads out wider by r (sec 12° − 1) $= 4{\cdot}8\ a \times {\cdot}0223 = {\cdot}097$ or say ·1 of the radius of the dome, or just half of the spread of the cone. The convexity would be disguised by one or more galleries round the top, as the slope of the drum is in St. Paul's, and as sketched on the right side here.

In the Beejapore dome I said the line of pressure might be taken from the inside of the dome to the outside of the drum because of the greatly superfluous thickness and stability of the dome. But not so in thinner domes, although we do reckon R at the bottom of a tied dome as diminished by taking the line of pressure inside, because if the outside is tied fast of course the inside is also. But an abutment or a drum is a different thing. For if the pier begins to turn over on its outer lower edge it opens under the outer edge of the dome and leaves that without any support; and it is only by considering P and Q as acting there when increased by t that we can get any stability at all. If the Gol Gomuz and its square drum were cut up into narrow strips it is actually not stable at the four nearest points of the walls; and if the slope of the drum is reckoned from the top of the drum itself, which comes nearly under the middle of the 10 ft. thickness of the dome, it is barely stable, as the walls are 116 ft. high and only 11 ft. thick, which is just short of a slope of ·1. I see that

Mr. Tarn came practically to the same conclusion. I need not repeat what I said of its stability as a whole being abundant, but it was necessary to explain this distinction between a tie and a drum in resisting the thrust at the bottom of a dome.

Tapered Domes.

When we have once found what will be a stable dome of any shape and thickness it may evidently be made more stable by diminishing its thickness upwards. For it is stable without any thickness down to 52°, and all the weight above that only adds to the bursting force below, and it is only wanted to increase gradually from 52° down to the bottom. The advantage of thickness above is purely geometrical, in shifting the breaking points, and is much more than counterbalanced by the effect of the weight due to the increase of thickness. The most stable kind of dome would be one built of the heaviest possible materials in the lower quarter and the lightest possible in the upper three quarters, so as to retain the geometrical advantage of thickness without the statical disadvantage. But as that is out of the question we must investigate the effect of tapering the thickness in some definite proportion. It may either increase downwards with x as the width of a lune does, making the weight increase with x, or with φ, or with $1-y$ the height and weight of any segment. The last is in every way the best, because it makes all the flattest and most oppressive part of the dome the lightest, whereas the thickness would increase much faster with x and leave a good deal of the upper part of the dome still thick and heavy. An increase with φ is a ratio between the two, but it has no advantage over the increase with the height, which is moreover much the easiest to calculate. That with x is troublesome and complicated, and with φ impossible in any moderate compass. Consequently I shall use that mode of tapering which reduces $2t$ at the bottom to t at the top, and makes t' everywhere $= t\left(1-\frac{y}{2}\right)$, and wherever I speak of a tapered dome without any other definition I shall mean one tapered in that ratio. We must consider the thickness to be taken off equally from the inside and the outside so as to keep the mean surface hemispherical for calculation, or else all the centres of gravity would be deranged. After we have got the results it will make no sensible difference to restore the hemispherical form to the outside or the inside as we please, only the latter is rather the more stable of the two.

The thickness $2t'$ now is everywhere $= t(2-y)$ or $2t\left(1-\frac{\sqrt{1-x^2}}{2}\right)$. We will call the weight cut off down to φ W, and the deductions from P Q R T in like manner $\underset{,}{\mathrm{P}}$ $\underset{,}{\mathrm{Q}}$, &c., and the resulting quantities for the tapered dome $\breve{\mathrm{W}}$ $\breve{\mathrm{P}}$, &c., and $\breve{x}$ $\breve{z}$ for $\bar{x}$ $\bar{z}$, &c. Then $\underset{,}{\mathrm{W}} = \int \frac{x}{2}\frac{\sqrt{1-x^2}}{\sqrt{1-x^2}}dx = \frac{x^2}{4}$, between the limits 0 to x for an arc φ and x to 1 for ψ, and x to x' for a middle arc. We may again omit t by dividing by 2, wherever t would occur, as $2t$ is still the thickness at the bottom of the dome and $2t'$ everywhere else. We see at once that the weight of the dome is reduced one fourth by the tapering. Then we shall have

$$\breve{\mathrm{W}} = 1-y-\frac{x^2}{4}. \qquad \therefore \frac{\breve{\mathrm{W}}}{1-y} = 1-\frac{x^2}{4(1-y)}. \qquad \breve{\mathrm{T}} = \frac{\breve{\mathrm{W}}y}{x} = \underset{\cdot}{\mathrm{T}} - \frac{xy}{4}$$

$$\mathrm{W}x = \int t x^2 dx = \frac{x^3}{6}. \qquad \breve{\mathrm{W}}\breve{x} = \mathrm{W}\bar{x} - \underset{,}{\mathrm{W}}\underset{,}{x} \qquad (\text{for } x \text{ is not } \bar{x}-x)$$

$$\acute{W} \text{ of } \psi = \frac{y^2}{4} \qquad \therefore \breve{W} = y - \frac{y^2}{4} \qquad \therefore \frac{\breve{W}}{y} = 1 - \frac{y}{4} \qquad \acute{W}\breve{\bar{z}} = \frac{1-x^3}{6}$$

$$\dot{P} = \frac{\acute{W}(1-\bar{z})}{y} = \frac{y}{4} - \frac{1-x^3}{6y} \qquad \therefore \breve{P} = 1 - \bar{z} - \frac{y}{4} + \frac{1-x^3}{6y} = \dot{P} + \frac{1-x^3}{6y} - \frac{y}{4}$$

$$\dot{Q} = \acute{W}\frac{1-x}{y} = \frac{x^2}{4y}(1-x) \qquad \therefore \breve{Q} = (1-x)\left(\frac{1-y}{y} - \frac{x^3}{4}\right) = \dot{Q} - x^2\frac{1-x}{4y}$$

So $\breve{R} = \dot{R} - \frac{x^3}{12(1-y)}$; and for a middle arc it would be $x - \underline{x} - \frac{x^3 - \underline{x}^3}{12(y'-y)}$

$\underline{x}$ being that for the same arc of an untapered dome or lune.

If we taper the dome to a third instead of half, t' at the top will be $t\left(1 - \frac{2}{3}y\right)$, and $\breve{W}$ becomes $\frac{2}{3}$ W, and all the other quantities are reduced in the same proportion, $\frac{y}{4}$ becoming $\frac{y}{3}$, $\frac{1+x^3}{6y}$ becoming $\frac{1-x^3}{4y}$, &c. We may also observe that in the lower arcs which alone we have to deal with $\breve{P}$ is very little less than the original $\dot{P}$, and may practically be taken as $= 1 - z - \cdot 001$ at once, or even as $1 - \bar{z}$ in very low arcs.

Since reducing the weight chiefly at the top evidently increases the stability of the dome, it will enable us to do with less thickness at the bottom also, and it is easy to find approximately how much. $\breve{T}$ now becomes a maximum ($\cdot 181$) at 58°; but in calculating how much lower the natural stability will be carried by thickness, we must remember that that is now variable, and $2t' = t(2-y)$. At 71° $2 - y = 1 \cdot 7$. Let us try $2t = \cdot 0333$, or three quarters of that for an uniform dome; then $2t'$ at 71° $= \cdot 028$, and sec 13° is only $1 \cdot 026$; ∴ the natural stability will be carried down to 71°; and there $\breve{T} = \cdot 155$, and $\breve{R}$ by the above formula is only $\cdot 1$: ∴ we must not use $\breve{R}$ but $\breve{T}$, which must be balanced by P + Q modified by t as follows:—

$$P = \frac{\acute{\breve{W}}(1-\bar{z}+t)}{y - yt'} = \frac{\acute{\breve{W}}}{y}(1-z+t)(1+t') = \frac{\acute{\breve{W}}}{y}\left\{1 - \breve{\bar{z}} + t + t'(1-\breve{\bar{z}})\right\}$$

$$= 1 - \frac{y}{4} - \bar{z} + \frac{1-x^3}{6y} + \left(1 - \frac{y}{4}\right)t + \breve{P}t, \ \breve{P} \text{ being the terms without } t.$$

$$= \breve{P} + t\left(\breve{P} + 1 - \frac{y}{4}\right) = \cdot 018 + \cdot 937t \text{ at } 71°$$

$$Q = \frac{\breve{W}(1-x+t+t'x)}{y - yt'} = \frac{\breve{W}}{y}(1-x+t+t'); \text{ and } \frac{\breve{W}}{y} = \frac{\breve{Q}}{1-x}$$

$$= \left(1 - y - \frac{x^2}{4}\right)\frac{1-x}{y} + \breve{Q}\frac{t+t'}{1-x}, \ \breve{Q} \text{ being the terms without } t.$$

$$= \breve{Q} + \breve{Q}\frac{t+t'}{1-x} = \cdot 077 + 2 \cdot 56t \text{ at } 71°.$$

By the same approximate calculation as we used for the uniform dome this gives us $3 \cdot 5t > \cdot 155 - \cdot 095 > \cdot 06$ ∴ $t > \cdot 017$ or $2t > \cdot 034$, which is only just above what we assumed; and we know by comparing this mode of calculation with the more complete and complicated one in the uniform dome, that it gives an error a little in excess of the true result, and ∴ we may be pretty

sure that ·033 was enough for the thickness of this tapered dome. Consequently a stable dome tapered to one half is only $\frac{3}{4}$ of $\frac{3}{4}$ of the weight of the lightest uniform stable dome of the same size.

We may infer that a dome tapered to one third, which thereby loses a third of its weight, may have its thickness at the base reduced one third too, and will ∴ weigh only $\frac{4}{9}$ of the uniform dome of the same size.

The tension at the bottom of a tapered dome may be considered =the maximum T, or P + Q modified by t, which has to balance T, which =·155 M. But the weight of the (half) tapered dome is only $\frac{3}{4}$ M, or $3\pi a^2 t$, and ∴ the resultant will have the same slope as in the uniform dome though the tie required is only $\frac{9}{16}$ as much.

Eyes in Domes.

Domes with an *eye*, or piece cut out at the top, and not replaced by a much heavier lantern, are so rare that it is not worth while to go into any minute calculation for them. The eye of the Pantheon dome has a radius of about 12° or ·2 of the radius of the base, and ∴ covers a 25th of the floor. But for illustration we will take one somewhat larger, say of 20°, which takes off ·06 of the weight of the dome. Let y' be that of the edge of the eye. Then T at any place $=(y'-y)\frac{y}{x}$, and is now a maximum at 56°; and ∴ a thickness of ·04 will carry the natural stability down to 72°, and the lower that goes the less thickness is always wanted for stability below. T there = ·204, and Q now becomes $(y'-y)\frac{1-x}{y}$ =·100. P remains $1-\bar{z}$ = ·017, and the coefficient of t in the approximate equation which we used before becomes $\frac{2y'}{y}-\bar{z}$. You will easily find that at 72° the equation is $5{\cdot}19t > {\cdot}087$, or t = ·017 would do, if we had not assumed it ·02 as above. If we had assumed it less, t would now come rather more, and we may be sure that ·02 is quite enough, instead of ·025, which that calculation gave before. And we shall be safe in saying that this removal of only a 17th of the weight by cutting out the eye enables us to reduce the thickness and ∴ the weight of the whole dome by a fifth. Conversely we shall see afterwards that the addition of a lantern requires a greater increase of thickness than the proportion of its weight to that of the dome.

Some domes have four or eight semicircular openings round the base. It is easy to calculate their effect when they are of moderate size, as they always are. If the eight openings are as wide as the solids left, the radius of each semicircle is $11\frac{1}{4}°$, and each cuts out $\frac{\pi}{8}$ of the zone $11\frac{1}{4}°$ high, or say $\frac{3}{8}$ of v. sin 11°, or nearly ·007 M. But the weight so near the bottom, where it is upright, has much less to do with stability than the spreading of the base by the thickness. The whole P or $1-\bar{z}$ for 11° is only ·005, and the part cut out is worth less than $\frac{3}{8}$ of this, because the c.g. of a semicircle is at ·43 of its height, while that of the zone is at half its height; and so the loss of P is insignificant. But the geometrical effect of cutting away the supports is more serious. For the lune over the centre of each semicircle has its supports transferred to places 11° off the centre, and the whole piece above the opening is carried, as it were, by a flat semicircle standing upright on the chord of 22°, which is v. s. 11°, or ·019, within the circle of the base, to which the middle lune ought to go: and that is equivalent to a reduction of t by nearly half its proper amount. Therefore the

right way to deal with such a dome is to carry the pieces that are left ·02 farther out (for ·019 × sec 11° is required to bring the chord to its proper place); or what is still better, tie the dome just above the openings. Their effect increases with their size very rapidly: *e.g.* if four semicircles of the width of 30° were cut out, the supports would have to be carried ·034 farther out, or to nearly double the thickness required for a close dome. Eyes in the middle of the height evidently rather increase the stability; and they will not make even the short lunes immediately above them unstable, because there is always plenty of superfluous stability at that height in a dome thick enough to be stable below.

Ribbed and Pannelled Domes.

In the discussion of 1859 it was taken for granted as requiring no kind of proof, that the best way to make a safe dome is with thick ribs and thin pannels, like Gothic vaulting. Of course if the ribs are very deep, or if they increase in width like lunes themselves, as they do in the Pantheon, they will be stable; but the question is, what is the best disposition of a given weight of materials? Take a dome of what we have found to be the least thickness for stability, and turn it into ribs and pannels, and see what would happen. For purposes of calculation we must dismiss the uncertain and (not in the usual sense) incalculable benefit of tenacity; and you cannot have the lower pannels without vertical joints in a dome of any size worth speaking of. Then the moment you reduce the just stable dome into thinner pannels you make them unstable, and certain to burst near the bottom if the bonding and cement fail to stop them. That is one way of looking at it. Another is to suppose all the dome at first as thick as the ribs are to be, and therefore very stable. Then cutting out the pannels is just cutting away nearly all the weight and thickness in the low parts where both weight and thickness tend to stability, and cutting away very little in the high parts where the weight tends to instability in a very high degree, as we saw in calculating the effect of an 'eye.'

Still, as there is some depth of ribs which will increase the stability of a dome we may as well find what it is. For when we know that, we may dispose of the pannelling by giving it a little horizontal curvature inwards (though that is directly opposite to the usual shape when pannelling has any horizontal curvature at all); and that will make the ribs take all the thrust of the unstable pannelling, provided they are deep and heavy enough themselves. For that purpose we must solve the problem of the arch, for which I can find no solution in any book, either mathematical or experimental, as to the requisite thickness for stability.

Arches.

No part of a round arch has any tendency to fall inwards except the top, or it will break as in the right side of the figure at p. 7 if it is too thin. T now $= \phi \frac{y}{x}$, which you may easily find from the table decreases from the very top, and $\therefore$ we have nothing to do with T, and must use R throughout; for which purpose we must find $\bar{x}$. W is now simply ϕ, and W′ for a lower arc is ψ. W $\bar{x}$ $= \int \frac{x\,dx}{\sqrt{1-x^2}} = C - y$, the unit being still the radius × width × thickness; and the limits being 0 to x for ϕ, and x to 1 for ψ, and x to x' for a middle arc $\phi' - \phi$ or $\psi - \psi'$ which we will call Δ.

$$\therefore \bar{x} = \frac{1-y}{\phi}, \quad \bar{z} = \frac{y}{\psi} \cdot \quad x = \frac{y-y'}{\phi'-\phi} \qquad \therefore \dot{P} = \psi \frac{(1-\bar{z})}{y} = \frac{\psi}{y} - 1$$

$$\dot{R} = \phi \frac{x-\bar{x}}{1-y} = \frac{\phi x}{1-y} - 1 \; : \; \underline{R} = \frac{\Delta(x-\underline{x})}{y'-y} = \frac{\Delta x}{y'-y} - 1$$

$$\dot{Q} = \phi \frac{1-x}{y} \qquad \therefore \dot{P} + \dot{Q} = \frac{90^\circ - \phi x}{y} - 1; \quad (90^\circ = 1{\cdot}57)$$

$$\therefore \dot{R} - \dot{P} - \dot{Q} = \frac{\phi x}{y(1-y)} - \frac{1{\cdot}57}{y} = \frac{\dot{R} - {\cdot}57}{y}$$

The following are some of the values of $\dot{R}$ which now decreases all the way down. The equation of stability $R < \phi \frac{y}{x}$ becomes $\phi < x$, which is impossible, and shows again that no part of a round arch is stable without the help of thickness.

$\phi =$	10°	20°	45°	50°	54°	60°	68°	78°	90°
R=	1·	·99	·90	·88	·85	·82	·76	·72	·57

To make the arch stable we must find such a value of t as will make $P + Q > R$ everywhere. In the same way as before we have

$$P = \frac{\psi(1-\bar{z}+t)}{y-ty} = \frac{\psi}{y}(1-\bar{z}+t)(1+t) = \frac{\psi}{y} - 1 + \frac{2t\psi}{y} - t$$

$$Q = \frac{\phi}{y}(1-x+t)(1+t) = \frac{\phi(1-x)}{y} + t\left(\frac{\phi}{y} + \dot{Q}\right); \; \phi + \psi = 90^\circ \text{ and } \frac{\phi(1-x)}{y} = \dot{Q}$$

$$\therefore P + Q = \frac{90^\circ - \phi x}{y} - 1 + t\left(\frac{\pi - \phi x}{y} - 1\right) = \dot{P} + \dot{Q} + t\left(\frac{\pi - \phi x}{y} - 1\right)$$

$$R = \frac{\phi(x-\bar{x}-tx)}{1-y+t(1+y)} = \left(\frac{\phi x}{1-y} - 1 - t\frac{\phi x}{1-y}\right)\left(1 - t\frac{1+y}{1-y}\right)$$

$$= \frac{\phi x}{1-y} - 1 - t\phi x - t\frac{1+y}{1-y}\left(\frac{\phi x}{1-y} - 1\right) = \dot{R} - t\left(\phi x + \dot{R}\frac{1+y}{1-y}\right)$$

$$\therefore t\left\{\frac{\pi - \phi x}{y} - 1 + \phi x + \dot{R}\frac{1+y}{1-y}\right\} \text{must} > \frac{\dot{R} - {\cdot}57}{y}$$

This gives the maximum value of t at or near 60°, where the equation becomes $6{\cdot}84\,t > {\cdot}507$, or $2t > {\cdot}144$, which is more than three times the thickness required for a dome: or a round arch of 100 feet span must be $7\frac{1}{2}$ thick, while a dome need only be $2\frac{1}{4}$. Or contrasting it in another way with the dome, where we found the thickness must be a 44th of the inner diameter and a 46th of the outer, that of the arch must be nearly a 13th of the inner and a 15th of the outer diameter. This is very nearly the same proportion as in the Gol Gomuz, where $2t = {\cdot}138$. Consequently a dome 100 feet wide and barely stable would not be helped by adding ribs any less than five feet deep,

except that where they converge near the top, they would in effect cut out a little of the dome, and so lighten it there; but the ribs themselves would only just be stable by the addition of the two feet of dome to them; and if we added ribs much less than five feet deep we should bring down the dome if its own tenacity did not preserve it.

The Gol Gomuz was very likely made of that thickness after trying the easy experiment of a round arch that will just stand; for any one capable of designing such a building would know that that thickness would be still more stable for a dome, though he might not know how much. So again the Pantheon may be described as generated by the revolution of a buttress and a flying buttress round an imaginary cylinder as wide as the 'eye,' and is much more stable than the buttress itself would be.

Tapering an arch to half its thickness at the top in the proportion to the height, as we did in the dome, reduces its weight by $W = \int \frac{t\sqrt{1-x^2}}{\sqrt{1-x^2}}\,dx = tx = \frac{x}{2}$ of the whole arch down to x, and $\therefore$ by ·5 at the bottom, where M is 90° or 1·57; $\therefore$ a tapered arch is reduced to 1·07 $a\,\beta\,2\,t$ (β being the width), or very nearly the weight of an untapered lune resting on the same base. But R is not reduced to its amount in a lune, because a lune is lighter at the top and heavier at the bottom than an arch tapered to only half its thickness, although their weights are equal. We should find that R is reduced by $\frac{x^2}{4(1-y)}$ =·25 at the bottom, where it is ·57 before reduction, which leaves it ·320 against ·215 in a lune thick enough to be stable. If we calculate P and Q also we shall come to this rather curious result that $R - P - Q$ everywhere in the arch =·25 or $\breve{R} - \breve{P} - \breve{Q}$ is reduced by that constant quantity. And calculating roughly, it seems that the thickness required at the bottom of a tapered arch is about $\frac{2}{3}$ of what it is in the uniform arch; which is analogous to the result of tapering a dome, where we found that the thickness may be reduced in the same proportion as the weight. Consequently if we added tapered ribs to the same dome as before, showing only 6 inches below the dome at the top, they must show 3 feet deep at the bottom, or they would do more harm than good. If they died into the dome at the top and came down to a depth of two feet at the bottom each rib would be nearly the same as a uniform lune of that thickness, and each such rib with a strip of dome over it would be rather more than stable because their thicknesses would be united. But all this is a long way from making up a stable dome of thick ribs and thin pannels, unless the ribs are so numerous as to make the dome much heavier than a uniform one, which again must be nearly twice as heavy as a tapered one without any ribs. In short the rib construction is a totally wrong distribution of any given weight of hemispherical dome.

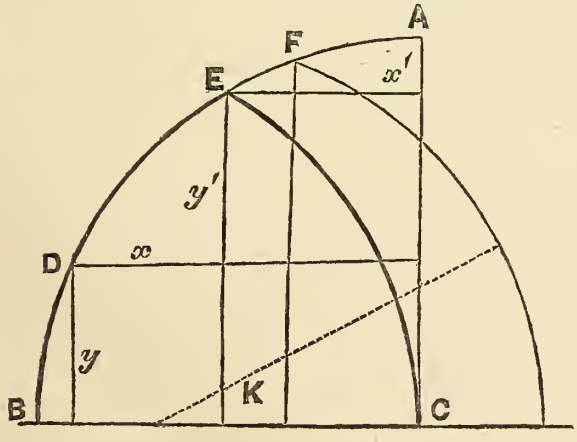
After writing this I was rather alarmed at reading in Gwilt's 'Cyclopædia' (§ 1498) that some French mathematicians had proved that an arch will stand with a thickness of only a fiftieth of its radius.* What that proposition means I cannot divine, for it is totally wrong in its natural sense, and I can find no other. The experiment may be tried very easily, as I will now show you, with a few children's bricks or other equal bits of wood; bevelling the edges equally so as to make them build into a semicircle, which you contract more and more by increasing the bevelling until you get it small enough to stand. The best way of observing the gradual approach to stability is to lay the arch flat on a smooth board with a ledge for the bottom of the arch to rest against and then slowly tilt the board up; the nearer it gets to upright before the arch falls the nearer you have got to the proportion of thickness and diameter which is requisite for stability. The board only helps the arch

* As translated from Rondelet's 'Art de Bâtir,' 4to, Paris, 1814, vol. iii. p. 382.

by friction, for the inclination does not alter the relative weights of the pieces. The corresponding experiment for a pair of lunes is not so easy, on account of their disposition to fall in at about 30° from the top and the impossibility of reducing the thickness to 0 at the top. But both these difficulties may be got over by substituting a piece of the proper weight reaching across as a chord from 30° to 30°. Its length may be anything you like, provided the weight is ·134 of the weight of a complete pair of lunes; which may also be of any width you like at the bottom, say 3 inches (not curved horizontally); and $\therefore$ $3x$ everywhere else up to 1·5 at 30°. If the piece representing the chord of 60° is of the same thickness as the rest, its outer or larger surface, to be of proper weight, must be $\cdot 268\, a d$, a being the outer radius and d the width of the bottom of the lunes. We know that a must be only 22 times the thickness of the pieces. One side must be made square to the two adjacent ones and the width reduced all on the other side, to make them lie flat on the board, or they will shake out of their places and fall when it is tilted. I exhibit this experiment also for the benefit of those who distrust mathematics, or who remember that mathematicians sometimes make mistakes.

Pointed Domes.

We have yet to consider domes of pointed arch section, like those of St. Peter's and Florence, and probably most of those which carry lanterns; for mechanical and artistic considerations agree in pronouncing hemispherical domes inferior to pointed ones for that purpose. The dome of St. Peter's is a little stilted and a little pointed, and the Florence dome is not far from one of 60°; and as that makes the calculation simpler than any other, we will take it for our example. We have now to observe that the radius of curvature, which is necessarily our unit of length since all the x's and y's are sines and cosines, is no longer half the span of the dome, but is *the* span in an arch of 60°, and so nearly $\frac{2}{3}$ of the span in one of 70°, that we may practically treat it so.



E or F, the top of the dome, will be ϕ', reckoned from A the top of the quadrant as before. A pointed dome is generated by the revolution of part of a quadrant round the upright chord EK or FK, which is not the radius; and the horizontal radius of the dome everywhere is $x - x'$, x' being the distance of that chord from the centre, or $x' = \sin \phi'$.

As we know where the c. g. of an arc is we can find the surface or mass of a thin pointed dome at once by a remarkable rule well known to mathematicians, that the surface or the mass of any body of revolution is the revolving line or area (none being cut off by the axis) $\times$ the path of its c. g. $= 2\pi(\bar{x} - x')$ in this case. We found before that $\psi x = y$ (p. 19) $\therefore$ the mass of the whole dome $= 4\pi a^2 t\,(y' - x'\psi')$, t being half the thickness as usual; and the mass of any zone $\psi = y - x'\psi$, omitting the constants as before. Consequently the mass of a dome of 60° $= \cdot 866 - \frac{1 \cdot 047}{2}$ (x' being $\frac{1}{2}$) $= \cdot 343$. But this is ·343 of $4\pi a^2 t$, and

a = twiee the radius of the base or = $2b$, and $\therefore$ this pointed dome = 1·372 of a hemispherical one on the same base; but its height is 1·732 of the hemisphere, and $\therefore$ a eylinder of that height and base is now eonsiderably heavier than the dome.

The mass of a dome of 70° is $\cdot 94 - 1\cdot 22 \times \cdot 342 = 2\pi \cdot 523\, a^2 = 2\pi\, 1\cdot 177\, b^2$, as $a = \frac{3}{2} b$; and the height is 1·4 to 1 of the hemisphere on the same base.

The element of a lune of a pointed dome, $dm = d\varphi\,(x - x')$, omitting $a^2 t \beta$ as before, $= \frac{(x - x')\, dx}{\sqrt{1 - x^2}}$, x' being eonstant.

$\therefore$ $W = \int dm = y' - y - (\varphi - \varphi')\, x'$ for an upper arc of the dome, whieh is now a middle arc of the quadrant,

and $\underset{,}{W}$ of a lower arc $= y - x'\psi$ Call $\psi - \psi$ or $\phi - \phi'$ } Δ, and put $\underline{x}$ and z for *c.g.*

$$W\underline{x} = \int \frac{x^2\, dx}{\sqrt{1 - x^2}} - \int \frac{x x'\, dx}{\sqrt{1 - x^2}} = \frac{\Delta + x'y' - xy}{2} - x'\,(y' - y) \text{ (upper are)}$$

and $\underset{,}{W} z = \frac{\psi + xy}{2} - x'y$ (lower) $= (\bar{z} - \acute{x})\, y$ ($\bar{z}$ being that of the table for eommon dome).

$$\dot{R} = \frac{W\,(x - \underline{x})}{y' - y} = x + x' - \frac{x x' \Delta + \frac{1}{2}(\Delta + x'y' + xy)}{y' - y}$$

$$\therefore \quad \dot{R} \text{ at bottom} = 1 + x' - \frac{x'\psi + \frac{1}{2}(\psi + x'y')}{y'} = 1 + x' - \frac{x'\psi'}{y'} - \bar{z}$$

$= \cdot 052$ M in a dome of 60°, whieh is ·208 of $\underset{,}{M}$ on the same base, or $4\pi t b^2$, and

$= \cdot 082$ M in a dome of 70°, whieh is ·184 $\underset{,}{M}$.

$\dot{P} = \underset{,}{W} \frac{1 - \bar{z}}{y}$, which will not sensibly differ from $\dot{P}$ or $1 - \bar{z}$ in any such low arcs as we shall have to deal with.

$$\dot{Q} = W \frac{1 - x}{y} = \frac{y' - y - x'\Delta}{y}\,(1 - x).$$

We have also to eonsider T, which now $= (y' - y - x'\Delta)\frac{y}{x}$, and see where it eomes to a maximum. In a dome of 70° it does so at 62°, where T = ·119; and in one of 60° T is ·065, and a maximum at 68°. In guessing at any value of t for trial we must remember that t is in terms of a and $\therefore$ has twiee its apparent value in a dome of 60° where $a = 2b$.

Let us try $2t = \cdot 012\, a$ whieh will earry the natural stability to 77°, or say 76° to be quite safe. Then T = ·056 and $\dot{R}$ is sensibly the same (as in the hemisphere at 68°), and we might use R modified by t as in the areh. But as we used T in the hemisphere, both beeause it is simpler and makes the error of approximation certainly on the safe side (whieh is not the ease with R) we had better do so now. If we used R the t term belonging to it is about ·45 t at 76° or anywhere near there, but that we shall omit.

$$P = \frac{W'(1-z+t)}{y(1-t)} = 1-\bar{z}+t(2-\bar{z}) \text{ since } \dot{P} \text{ sensibly } = P \text{ for these low ares.}$$

$$Q = \frac{W(1-x+t\overline{1+x})}{y(1-t)} = \frac{y'-y-x'\Delta}{y}(1-x+2t) = \dot{Q} + \frac{2\dot{Q}t}{1-x}$$

At 76° $P = \cdot 011 + 1\cdot 01\, t$, and $Q = \cdot 027 + 1\cdot 82\, t$; $\therefore \dot{P} \div \dot{Q} = \cdot 038$ $\therefore$ $2\cdot 83\, t$ must $> \cdot 056 - \cdot 038 = \cdot 018$ $\therefore$ $2t > \cdot 01375\, a$ or $\cdot 0275\, b$, which is rather more than we assumed for trial. And no place below 76° requires a larger t, though 72° or 74° does apparently, but not really, because this formula does not apply till we reach the end of the natural stability. Thus we see that a dome of equilateral section 100 feet wide (*i. e.* $a = 100$) only need be $16\frac{1}{2}$ in. thick, or $\frac{5}{8}$ of what a hemisphere requires. We may infer that a dome of 70°, in which b the half span $= \frac{2}{3}a$, requires about $\frac{3}{4}$ of the thickness of a hemisphere, or $\cdot 033\, b$.

Tapering does not benefit pointed domes as much as hemispheres, for the obvious reason that they have already lost the most oppressive part of their weight, the flat top of the hemisphere. The weight of a pointed dome is reduced by $\frac{1-x'^2}{4}$ by tapering it to one half, which is about a 9th in a dome of 70° and only a 16th in one of 60°.

R at the bottom of a dome of 60° thick enough to be stable $= \cdot 052$ M (M being $4\pi t a^2$); and W is $\cdot 343$ M: $\therefore$ R $= \cdot 151$ W. Also in a dome of 70° R $= \cdot 082$ M, and M $= \cdot 184$ W. $\therefore$ R $= \cdot 150$ W. Therefore either of these domes will stand without any tie upon a drum with an initial slope of $\tan^{-1} \cdot 15$ or nearly 9°, while a hemisphere requires 12°, and the drum itself may be of convex outline according to the construction given at p. 14.

We can now also verify that conclusion as to the drum which will support a stable hemisphere, the drum being as high as the dome for simplicity. We found that the φ' of such a dome is 50° (corresponding to 30° in what we call a dome of 60°). Keeping a for the radius of the original dome, and r for the radius of curvature of the drum, W down to 78° of the pointed dome $= y' - y - x'\Delta = \cdot 062\, r^2 = \cdot 062 \times 23\, a^2$ (since $r = 4\cdot 8\, a$) $= 1\cdot 42\, a^2$, or nearly half as much again as the hemisphere. Again T at $78° = W\frac{y}{x} = 1\cdot 42 \times \cdot 21\, a^2 = \cdot 298\, a^2$; instead of $\cdot 2\, a^2$ as it is in the hemisphere: $\therefore$ both the weight and the thrust of the hemisphere are much less than those of the pointed dome which would complete the drum, and it will be abundantly safe, independently of its requiring less thickness for its own stability as a pointed dome. And we may now conclude that in all cases the drum to support an untied stable dome may be designed geometrically like that at p. 14, whatever is the intended height of the drum. The drum is of course assumed to go down either to the ground or to the transepts of the building and to have proper support there, for its thrust outward is practically no less than that of the dome, its own weight making no sensible difference in that respect.

Pointed Domes with Ribs.

A pointed arch is well known to be better fitted for bearing weight than a round one, and $\therefore$ it may be thought that a pointed dome will be more helped than a round one by ribs not much deeper than its own thickness. Let us see how that is. In a pointed arch of 60° (*i. e.* $\phi' = 30°$) $T = (\phi - \phi')\frac{y}{x}$ or $\Delta\frac{y}{x}$, and this is $\cdot 3$ and a maximum at 60° from the top of the quadrant. Con-

sequently an equilateral arch has a tendency to fall in through its upper half and out through its lower, though a round arch thrusts outwards everywhere except at the top. A dome rib is prevented from falling in, but that inward pressure goes to increase the outward thrust below, unless it is counteracted by sufficient thickness. As we know that considerable thickness is requisite for an arch let us try $2t = \cdot045$ of the radius of curvature and span of the arch of 60°. That carries the natural stability down to 77°, sec 17° being 1·0456. Anywhere about there R or $\frac{\Delta x}{y' - y} - 1$ is considerably > T, and ∴ we must use R and not T. I find that 80° is the place of maximum t, and there

$$\mathrm{R} = \dot{\mathrm{R}} - t\left(\Delta x + \dot{\mathrm{R}}\frac{y' + y}{y' - y}\right) = \cdot245 + 1\cdot238\, t$$

$$\mathrm{Q} = \Delta\frac{1 - x}{y} + \frac{\Delta t}{y} + \dot{\mathrm{Q}}\, t = \cdot075 + 5\cdot075\, t$$

P is insignificant except that it adds $t\left(\frac{2\psi}{y} - 1\right) = t$ sensibly: ∴ $\mathrm{R} - \mathrm{P} - \mathrm{Q} = \cdot17 - 7\cdot307\, t$; ∴ t must > ·0233 a or ·0466 b against ·072 b in the round arch (p. 19); which is a little more than we assumed, or the thickness of these ribs (including the dome) must be ·0466 of the diameter, or 4 ft. 8 in. in a dome 100 ft. wide, which is four times the necessary thickness of the dome itself, a rather higher proportion than was required for the ribs of a round dome if they were to do any good. So that the rib construction is the worst for any kind of dome.

Lanterned Domes.

As all the great domes built within the last 500 years are loaded with heavy lanterns at the top, it is necessary to consider their conditions of stability. A lantern of any considerable weight produces such a bursting pressure all over the dome that we may at once dismiss all consideration of natural stability, or stability independent of thickness, since the dome to carry a heavy lantern must be so thick that a pair of lunes would stand without falling in even if the lantern were removed.

If L is the weight of the lantern beyond that of the eye cut out to receive it, T would be $(1 - y + \mathrm{L})\frac{y}{x} = \dot{\mathrm{T}}$ (of the table) $+ \mathrm{L}\frac{y}{x}$.

We can only deal with L as some fraction of our unit of mass M; and if L = ·1, T has no maximum, or there is no inward pressure, as in an arch. If L is anything from ·05 to ·07, T will have a maximum at 45°; L = ·08 raises the maximum T to ·374 at 42°, and ·09 to ·385 at 40°. But even the smallest of these requires a thickness large enough to make a pair of lunes stable inwards. And in that case we must deal with them by R instead of T, as we did in the arch, and consider how R is modified by thickness, and we shall have

$$\mathrm{R} = \frac{(1 - y)(x - \bar{x} - tx)}{1 - y + t(1 + y)} = \dot{\mathrm{R}} - t\left(x + \dot{\mathrm{R}}\frac{1 + y}{1 - y}\right);\ \text{and as before}$$

$$\mathrm{P} + \mathrm{Q} = \dot{\mathrm{P}} + \dot{\mathrm{Q}} + t\left(\frac{2}{y} - \bar{z}\right).$$

But we now have two new horizontal forces introduced by L, one of which increases R and the

other Q. Apart from t, $R_l = \frac{L\,x}{1-y}$ and $Q_l = L\,\frac{1-x}{y}$; and introducing t

$$R_L = \frac{L\,(x - t\,x)}{1 - y + t\,(1+y)} = \frac{L\,x}{1-y}\,(1-t)\,\left(1 - t\,\frac{1+y}{1-y}\right) = R_l - \frac{2\,t\,R_l}{1-y}$$

$$Q_L = \frac{L\,(1 - x + t\,\overline{1+x}}{y + t\,y} = \frac{L}{y}\,\left\{1 - x + t\,(1+x) + t\,(1-x)\right\} = Q_l + \frac{2\,t\,L}{y}$$

Combining all these we shall have as the equation of stability for the lanterned dome,

$$t\,\left\{x - \bar{z} - \frac{2}{y} + R\,\frac{1+y}{1-y} + 2\,\frac{R_l}{1-y} + \frac{2\,L}{y}\right\} > R - P - Q + R_l - Q_l;$$

remembering that this equation is not applicable when $2\,t$ is $< \cdot 05$, because the term $t\,\left(x + R\,\frac{1+y}{1-y}\right)$ is then too large; but it is no use thinking of lanterns on a dome thinner than that.

I find that the largest t is now required at 60° for any moderate value of L or weight of lantern, and then the equation becomes

$$4 \cdot 66\,t - \cdot 072 > 1 \cdot 46\,L - 10 \cdot 93\,L\,t\,;$$

and that gives these results for a dome 100 feet wide at mean thickness, since M is about 1000 tons when $2\,t = 1$ foot or $\cdot 02\,a$, a being 50.

	Thickness $2\,t$	L	Tons.	$(4\,t)^3 \times 88$
$\cdot 05\,a$	$= 2\frac{1}{2}$ ft.	$\cdot 038$ M	$= 95$	110
	3	$\cdot 06$	180	190
	$3\frac{1}{2}$	$\cdot 084$	294	301
	3·78	$\cdot 1$	378	380
	4	$\cdot 1122$	449	450
	$4\frac{1}{2}$	$\cdot 1425$	641	641
$\cdot 1\,a$	$= 5$	$\cdot 177$	880	880

The $(4\,t)^3$ is only multiplied by 88 to show at once the near equality of the ratio of the weight of the lantern to the cube of the thickness of the dome.

This equality is so near that it would probably be exact if our formula were not an approximate one. It is impossible that such a result, holding through such wide limits, can be accidental; and it is *à priori* probable, because a lune must increase in strength with the square of its thickness as a curved beam, and it increases in stability against the lantern besides, by the lower part being so much wider than the upper, and ∴ gaining more weight by an increase of thickness.

If $L = \cdot 1$, R at the bottom or the tie required$= \cdot 215 + \cdot 1$, and ∴ the resultant of $\frac{R}{W} = \frac{\cdot 315}{1 \cdot 1}$ $= \cdot 287 = \tan 16°$ instead of 12°, as it was without a lantern. I omit the comparatively small modification of R by t which I gave before, as there must be at least that margin left for safety.

L represents any other weight as well as a lantern, such as snow, and indirectly even wind, for which I do not pretend to calculate directly. Its effect on an unlanterned dome must be very small, for the only part which presents anything like a flat surface to the wind, say, on the west side, is just that which is strongest against external pressure; and before that can reach the other

parts of the dome, it must either push the north and south sides lengthwise, twisting all the lunes there, or lift up the top, which is quite out of the question. A dome must be the strongest of all structures against wind, except perhaps a cone. And all the snow that could fall upon it in a year in this country would be a perfectly insignificant weight for any dome of moderate stability. The effect of wind upon a large lantern at the top of a dome is far more serious, and when that is ascertained by experiments it may be treated as equivalent to so much extra weight added to the lantern on the side away from the wind at the time, and the dome must be thickened accordingly.

Lanterned tapered Dome.

Though a tapered dome requires only $\frac{3}{4}$ of the thickness of an uniform one, it by no means follows that we may first taper off a quarter of the weight, and then put it all on the top as a lantern. We saw in the calculation for the *eye* how much more oppressive weight is at the top than anywhere else. Suppose we add a lantern whose weight exceeds that of the eye cut out for it by L, then T has $\frac{Ly}{x}$ everywhere added to it, and T for the tapered dome becomes $T - \frac{xy}{4} + \frac{Ly}{x}$. If $L = \cdot 05$ the maximum T is thereby raised again to 50°, where it $= \cdot 219$; and if $L = \cdot 06$, or anything higher, T will have no maximum, or no part of the tapered dome with that lantern will be stable without the help of thickness. And I find by a calculation which I need not give in detail, as it leads to no new practical result, that a tapered dome will bear so little more weight on the top than an untapered one of the same thickness at the base, that it is not worth considering. The place of maximum t now seems to be about 70°, and the equation for L and t there is this, approximately as before:—

$$4 \cdot 13\, t - \cdot 058 > 1 \cdot 22\, L - 8 \cdot 2\, L\, t$$

which makes $2t = \cdot 073$ instead of $\cdot 0756$ if $L = \cdot 1$; and $L = \cdot 045$ instead of $\cdot 038$ if $2t = \cdot 05$.

Pointed Domes with Lanterns.

It is easy to foresee that a pointed dome will carry much more weight than a hemisphere, as it approaches nearer to a cone. If x' y' are those of the top of the dome as before, or sin 30° and cos 30° in a dome of 60°, $\underset{l}{R} = \frac{x - x'}{y' - y} L$; but $\underset{l}{Q} = \frac{1 - x}{y} L$, as in the hemisphere; and modified by t they are

$$\underset{L}{R} = \frac{L(x - x' - tx)}{y' - y' + t(1 + y')} = \frac{L}{y' - y}\left(x - x' - t\,x - t(x - x')\frac{y' + y}{y' - y}\right)$$

$$= \underset{l}{R} - t\left(\frac{Lx}{y' - y} + \underset{l}{R}\frac{y' + y}{y' - y}\right)$$

$$\underset{L}{Q} = L\,\frac{1 - x}{y} + \frac{2tL}{y} \text{ as before in the hemisphere.}$$

And these are to be added respectively to the T—Q of the dome. A lantern of any moderate weight raises the place of maximum t very little in a dome of 60°, and as it is still within the limits of natural stability of the dome alone, we must use T and not R. I find 74° is the place of maximum,

and there $\dot{T} = \cdot059$, and P + Q by the formulæ at p. 22 $= \cdot04 + 2\cdot45\ t$; and $R - Q = \cdot655\ L - 10\cdot38\ L t$. Combining all these we have for the equation of stability,

$$2\cdot45\ t - \cdot019 \ > \ \cdot655\,L - 10\cdot38\,L\,t.$$

This gives the following results for thickness and weight of lantern on an equilateral dome 100 feet wide, after multiplying L by 4 to express it in terms of M the weight of a hemisphere on the same base or $4\pi b^2 t$, for M = about 1000 tons when $2t$ is one foot and b is 50. The tons in L are ∴ the number of L × the thickness in feet × 1000.

Thickness $2t$.	L	Tons.	$(4t)^3 \times 2$
2 feet.	·044 M =	88	128
$2\frac{1}{2}$	·1052	263	250
3	·142	425	432
$3\frac{1}{2}$	·2	700	686
2	·268	1072	1024

This shows that the weight of the lantern still increases nearly as the cube of the thickness, as in the hemisphere, though the thickness is less.

But practically no dome with a heavy lantern should be left without ties somewhere above the base, and indeed all domes would now be built with hoop iron in all the lower courses, which would enable their weight to be reduced to much less than the proportions given as the result of these calculations, as we saw in the dome tied at 80°. In fact if the ties are carried up to where the natural stability ends, you would theoretically want no thickness at all. Let us now apply this mode of calculation to a lantern on a hemispherical dome, making some probable assumption as to its weight, and taking some thickness and ∴ weight of dome for trial. Let L be 150 tons, and the dome $2\frac{1}{2}$ feet thick and 100 wide, and ∴ M = 2500 tons, which makes L = ·06 M, or more than that dome would carry if tied only at the base. To find where the natural stability ends we have $T = (1 - y + L)\frac{y}{x} = T + \cdot06\frac{y}{x}$, which is ·353 and a maximum at 45° or somewhere very near it. $2\frac{1}{2}$ feet = ·05 a (a being 50 feet) which carries the stability 18° lower or to 63°, and if the dome is tied there it will stand, so far as the mere weight of the lantern is concerned; but as wind as well as weight has to be provided against, the ties should be carried up higher; for every increase of L, which the wind force on it amounts to, raises the limit of natural stability, and if L is > ·09 there is no natural stability apart from thickness.

The strength of the tie required at 63° is the difference between T there and P + Q from below, as we found in the unlanterned dome tied at 80°. In all these cases where we treat the thrust of the upper part of a dome as represented by T, we consider it as acting on the wedge principle on the parts below, subject to the qualification stated at p. 9. It is unnecessary to add other examples, as they may easily be deduced from the foregoing formulæ adapted to other pointed domes. In what we call a dome of 70° $x' = \sin 20°$ and $y' = \cos 20°$, and the weight of L will probably be something near a mean between L for the hemisphere and for a dome of 60°.

Arches carrying a Lantern.

The proposition is almost self-evident that a pointed arch will carry as much weight as would complete it into a round arch thick enough to be stable; but this does not come to much, for it only means that an arch of 60° will carry half its own weight if thick enough to be stable as a round arch, *i.e.*, about a fourteenth of the span of the round arch, or a seventh of the pointed one (p. 19). Consequently a set of ribs, or flying buttresses, will carry no great weight unless they are nearly thick enough to contain a straight line, in which case their strength is mathematically infinite, *i.e*, they will stand until the stones are crushed at the edges. It is the weight of the dome that resists the lantern, carrying all the thrust to the bottom of the dome. The best flying buttresses do contain a straight line amply.

The double shell of domes joined by ribs on St. Peter's and Florence Cathedrals, and the treble one of the Pantheon at Paris, are a very imperfect imitation of the principle of bones and quills and hollow iron pillars, since it is essential to their strength that each side should possess tenacity as well as resistance, which masonry practically does not. But the two shells are useful as taking a firmer hold of the lantern to prevent it from being turned over by the wind. Otherwise they would be stronger as mere domes if their thickness were all in one, even without any ribs, provided the stones are made as good as *throughs* in the lower part: in fact they would be a great deal more than stable; and contain materials enough to make very much larger domes if they were freed from the incubus of lanterns and the thickness tapered. We have seen that a hemispherical dome 200 feet wide need not be quite $3\frac{1}{2}$ feet thick if it is half that thickness or anything less at the top, and its weight upon the drum would only be the same as of the drum itself of the same thickness continued 75 feet higher if the dome is tapered to 21 inches at the top; and 66 feet if tapered to 14 inches. Such a dome would enclose rather more than twice the area of St. Peter's, and nearly four times that of our St. Paul's. According to the best authorities, the internal diameters of all the masonry domes above 100 feet are:—Pantheon 142; Florence Cathedral $138\frac{1}{2}$; St. Peter's $137\frac{1}{2}$; Beejapore 137; Mousta in Malta 124, and St. Carlo of Milan 105, both built in this century; St. Sophia 105; St. Paul 102. The Florence dome is octagonal.

Though it is the fashion to condemn what is called the sham construction of our metropolitan dome, there a good deal to be said for it. In the first place, as St. Peter's dome is covered with lead it has no visible superiority over St. Paul's in being made of bricks instead of wood. And when we look at the lantern of St. Paul's, proportionately larger than St. Peter's, standing with absolute safety upon that thin cone of 18 inches, with the equally thin dome below, and compare them with the huge mass of masonry in St. Peter's and Florence, or with the three shells in the much smaller dome of the Pantheon at Paris (for which I refer you to the sections which Mr. Donaldson kindly exhibits for me, made some years ago from his own measurements), I cannot help pronouncing in favour of what every one admits to be the grandest dome externally and which is certainly managed in the most scientific way. Although Wren was an Oxford professor of mathematics before he was an architect, he had probably not solved the problem of the dome, for the integral calculus had not then been invented by Newton, without which it cannot be done. But by mathematical or mechanical instinct he came to the right conclusion as to the proper way to carry a lantern with the smallest load upon his piers.

I need hardly remind you also of the science displayed in bringing down the cone so low that its slope is only 24° or thereabouts, which diminishes the thrust immensely, while the inner dome is

quite high enough, springing from the base of the cone, instead of rising nearly from the same base as the outer dome at St. Peter's and Florence. Even now, with the knowledge that we have of what can be done in pure dome building with the aid of hoop iron, I should recommend the very same construction for two domes and a lantern, except that the outer dome should be a real one, as it might be easily.

Cones and Spires.

It is by no means so simple a matter as might be expected to investigate the tension at the bottom of a cone or spire of moderate thickness, though it is easy enough when they are either very thick or very thin. When it has no sensible thickness the thrust at the bottom is simply that which that we have called T throughout or the weight $\times$ the tangent of the slope or inclination to the vertical, or W tan α, α being the slope of the cone or half the angle at the top. A hollow cone is composed of an infinite number of narrow triangular strips analogous to the lunes of a dome, of which the base is $a\beta$ if a is the radius of the base and β the small angle which becomes 2π by integration. Taking $2t$ for the thickness as before, and l the oblique height, or the length of each elementary triangle, $W = a l \beta t$, and omitting $2\beta t$ as common to all pieces of such triangles,

$$W = \frac{a l}{2} = \frac{a^2}{2 \sin \alpha} \qquad \therefore T = \frac{a^2}{2 \cos \alpha}.$$

If $\alpha = 24°$ as at St. Paul's, T = ·545 M, M being $4\pi t a^2$ or the mass of a hemispherical dome of the same size and thickness. It must be remembered that a cone of $2t$ thickness will not stand on a ring $2t$ wide, because the horizontal thickness is greater, being $\frac{2t}{\cos \alpha}$; and if you wish to use the vertical height h instead of the oblique you must put $\frac{h}{\cos \alpha}$ for l, or $ht' = lt$, $2t'$ being the horizontal thickness, or the width of the ring on which the cone stands. The T of a right-angled cone, or one contained within the hemisphere, α being 45°, is ·707 against ·215 the thrust of the dome itself. So that the infinite stability of the cone resolves itself into more than three times the thrust of the containing dome which is 1·4 times its weight, and into nearly five times the thrust of a dome of the same weight and the same width.

Again comparing a cone of $\alpha = 30°$ with an equilateral dome of the same width, we found R = ·208 M at the bottom (M being the hemisphere on the same base) while T of the cone = ·577 M.

This assumes that the cone is so thin that it would open at or very near the bottom, and that no long strip of it would hold together by virtue of its thickness. The calculation of how much would so hold together is much more complicated than for a dome, and not worth going into here, as it is evident without calculation that no long piece of a narrow leaning triangle of stone could hold together without very great thickness. If you calculate the two forces that we have called P and Q at any place where x is the horizontal ordinate, and y the vertical from the bottom, without t, P + Q will be the thrust. Let W be the mass of the whole strip of cone, $\acute{W}$ that of the upper part down to x, and $\underset{\prime}{W}$ of the lower, $\bar{z}$ the distance of c. g. of the lower piece from the axis.

Since the c. g. of any triangle is at $\frac{1}{3}$ of its height from any side on which it stands $\bar{x} = \frac{2}{3}x$ and a for the whole $= \frac{2}{3}a$ $\therefore$ $\mathrm{W}'\bar{z} = \frac{2}{3}(\mathrm{W}a - \mathrm{W}'x) = \frac{a^3 - x^3}{3 \sin \alpha}$ since $\mathrm{W} = \frac{x^2}{2 \sin \alpha}$.

$$\therefore \mathrm{Q} = \mathrm{W}' \frac{a-x}{y} = \frac{x^2}{2 \sin \alpha} \tan \alpha = \frac{x^2}{2 \cos \alpha}$$

$$\mathrm{P} = \mathrm{W}' \frac{a-\bar{z}}{y} = \frac{a^2 - x^2}{2 \cos \alpha} \frac{a}{a-x} - \frac{\mathrm{W}'\bar{z}}{y} = \frac{a^2 + ax}{2 \cos \alpha} - \frac{a^3 - x^3}{3 \cos \alpha}$$

$$\therefore \mathrm{P} + \mathrm{Q} = \frac{a^2}{2 \cos \alpha} \left\{ 1 + \frac{x}{a} + \frac{x^2}{a^2} - \frac{2}{3} \frac{1 - \frac{x^3}{a^3}}{1 - \frac{x}{a}} \right\}$$

which becomes $\frac{a^2}{6 \cos \alpha}$ when $x = 0$ or the strip of cone is thick enough to hold together up to the top: which $=$ R for the whole cone calculated as P was just now; and when x approaches infinitely near to a, P+Q comes infinitely near to $\frac{a^2}{2 \cos \alpha}$ or T. Putting $x = a$ will not do because it then involves $\frac{0}{0}$, which may be anything, and is in fact 3, as you may see by putting $x = .999\ a$.

With any moderate thickness the cone would begin to break much nearer the bottom than the top if the tie failed. If it breaks at a 4th of its height $x = \frac{3a}{4}$, and then P+Q is about .77 T: at one third of the height it is .7 T, and at half the height .58 T; and if it is so thin as to break at .1 of its height, P + Q + .91 T: which is a rough approximation to the rule that $\frac{\mathrm{P}+\mathrm{Q}}{\mathrm{T}} = \frac{l'}{l}$, l' being the length of the piece of cone which remains solid and l the whole length. As I said before, the calculation of l' for any given t is too long to undertake here.

I will mention here a simple rule for finding the mass of thin hollow cones, whether complete or truncated, which I have not seen in any book. Such a cone $=$ a cylinder of the same thickness whose height $=$ the slant side of the cone and whose diameter is the mean diameter of the cone, *i. e.* mean between top and bottom whether the top is or is not a point, and also at the mean thickness, as we have reckoned in all cases. This may easily be deduced from what I have already given as the mass of a complete thin cone.

Polygonal Domes and Spires.

All the foregoing calculations apply also to polygonal domes and spires with very little modification. If each side may be considered as composed of long horizontal stones like boards it would be exactly the same as a narrow lune, for the width of each course increases in the same ratio as a lune of a dome of the same vertical section through the middle of a pair of opposite sides: or even if each side may be considered as divided into strips which will each increase in the same ratio as the whole side, though obliquely except the middle one. And practically it may be so considered. The

middle lune of each side will then be like a lune of a rather pointed dome if the vertical section through the angles is a semicircle; for the base of that lune is only ·92 from the centre of the dome: which is the more favourable to stability. Therefore whatever thickness would be sufficient for a round dome of the section through the angles will be rather more than sufficient for the polygonal one. It is true that theoretically the middle lune of each side could fall in near the top; but practically it could not, even if the thickness requisite for stability outwards at 70° were not enough for stability inwards at 20°, as it is, in a hemispherical uniform dome.

These seem to me the principal problems of dome-building, and though of course there may be others I should think that they may all be solved by the application of the principles here laid down. This paper has run to an unexpected length, but I do not see how I could have curtailed it without omitting what is material to a full understanding of the subject.

Mr. F. C. PENROSE, Fellow.—I have great pleasure in rising to propose a vote of thanks to Mr. Denison for bringing this very interesting subject before us. We shall look forward with much interest to having the paper in a printed form, that we may be enabled to verify for ourselves any points that may seem to require it. Our thanks are especially due to Mr. Denison for having put the subject before us freed from an abstruse condition, with which mathematicians have often complicated the question, namely, by dismissing from his consideration all tendency among the separate stones to slip one upon the other, and at the same time, whilst repudiating *friction and sticktion*, he retains so much of it as to suppose that large segments of his arches and domes can turn upon certain joints, as hinges. All this seems to have been carefully considered, and I have no doubt when the paper is before us, it will materially assist us in the consideration of this matter. I am also much gratified with the view Mr. Denison has taken of the construction of the dome of St. Paul's; and fully concur with what he has said about the judgment shown in the support of the lantern, and certainly if there were funds available for the substitution of a stone dome for the lead-covered external timber dome, I should be glad to see it. I cannot but think that it would be very desirable for the discussion to be carried on to another evening, after we have had an opportunity of reading the paper, but I particularly desire to have the privilege now of moving a vote of thanks to Mr. Denison for his very able paper.

Mr. WYATT PAPWORTH, Fellow.—In seconding this well deserved vote of thanks, I have very little to add, beyond stating that I have been greatly pleased and interested by the observations we have heard on this subject, which is one that has attracted my attention on several occasions, but I have never been able to go into the mathematical question as Mr. Denison has now done. It appeared to me that the learned gentleman rather disparages the dome of the Church of S. Vitale at Ravenna, and that of St. Sophia. For my own part, I thought they both exhibited the same sort of construction that he considers necessary for stability, in having weight and substance at the bottom to resist that line of thrust he has so clearly elucidated. The paper, to which reference has been made to night as likely to follow this one, is hardly to be considered as analagous to it, because it relates the fall of a dome of a church at St. Petersburg, about six years since. It has taken nearly that length of time to obtain the manuscript, which reached my hands in the Russian language, and there was great difficulty in getting it translated in London, owing to the numerous technical terms. It has now been translated, but I almost hesitate to read it after the capital discourse we have heard this evening. However, as my paper attributes the failure of the dome to some of the pillars giving way, and as it explains a theory prepared for rebuilding the church, so as to resist the thrust of the dome, it may prove of some interest, if only as a record of a failure. I have the greatest pleasure in seconding the proposition of a vote of thanks to Mr. Denison.

Mr. E. NASH, Fellow.—Will you allow me, Sir, to offer my mite of congratulation to this Institute upon the fact of a gentleman of Mr. Denison's earnest mind and high attainments coming here to assist us in respect of scientific methods of construction, and especially of dome construction? I am not aware of any satisfactory mathematical theory of domes having yet been promulgated. On the theory of arches we have had a plentiful supply of formulæ, and they are well understood; but the theories of arches are in a great measure inapplicable to domes, and I am not sure that very minute mathematical theory is essential for domes. Do not misunderstand me; I do not say that we do not want scientific theory, for it is one of those things which give to all we do a certainty and reality which man's instinct is insufficient for him to obtain, but which he may obtain through his reasoning powers. However, in considering domes as distinguished from arches, suppose we take the lune of a dome, and divide it into two equal parts of height, we find the base to be very broad, and that it rises to an infinite point at its apex. The upper half of that lune may be described as a convex triangle, the lower half as a convex trapezium; and the enormous amount of material in the trapezium portion being set against the small amount in the triangular portion, is very noticeable in respect of stability. The upper portion has great horizontal thrust but small weight; the lower portion has much less thrust and much greater ponderosity, which gives it immense advantage in resisting the thrust of the triangular portion. Then looking at the thing in a practical manner, discarding for the present all scientific formulæ, and using only an architect's natural sagacity, what is a dome? A dome being a ring, every ring can be keyed in one over the other. Many domes have been built without centering, showing that they support themselves; and I believe that every dome built of brick or stone could be erected without any centering, excepting in the upper portion, when a centering might be suspended from the completed portion. I believe that we have nothing easier to construct than a dome, and that the cause of our not using them more than we do, may arise from our climate or our habits. We have only a few capital instances of them, and all must admit their sublime effect. Look at the little dome over the rotunda of the Bank of England; small as it is there is a grandeur about it; and if that most excellent dome at the British Museum had been erected as a true dome of masonry, it would have been not only good, as it is, but perhaps a finer architectural achievement. I may be inclined to differ from the reader of the paper with regard to the thickness of domes, but as he has mathematical attainments which I do not possess, he is no doubt right and I am wrong.

Professor KERR, Fellow, (referring to the drawing by which the lecturer had explained the stability of a hemispherical dome, by showing two lines of imaginary support below a certain point, within the thickness of the domical structure).—If the crowning portion of the dome, to the extent of 60°, be taken to be stable of itself, I understand the doctrine to be, that with such a thickness for the dome as shall admit of its containing two successive tangents to the intrados, drawn within the remaining 30° of the quadrant, so that, looking upon these tangents as struts, the head of the one shall be level with the foot of the other, then the whole will be stable. In this case it seems to me desirable for the lecturer to explain to us a little more clearly whether the connecting link between these two struts (represented by a horizontal line from extrados to intrados) does or does not stand for a thing stable in itself, that is, a ring of construction, or what we call chain bond. I am for one extremely obliged to the distinguished and learned gentleman for his discourse to-night. The subject, which he has treated so very fully, is one which eminently deserves our attention, not only as scientific men, but as practical architects. It may be true that we have not many opportunities of constructing domes; at the same time it is apparent from what has been said—irrespective of the mathematical portion of the question, and looking at it with what Mr. Nash calls practical sagacity—that there is no subject, perhaps, on which we have more to learn in the way of general information and constructive theory. There are, however, certain points of building, rather than mathematics, which occur to my mind, upon

which Mr. Denison has not happened to touch. First I may speak of the question of bond. That is with us most important because we should never design a dome without using dowels or other bond to connect each course throughout, as a ring, and make it in itself a perfect tie; then when each ring is thus its own tie, the necessity for nice mathematical calculation to a great extent disappears. At the same time I do not for a moment disparage the importance of the theory which Mr. Denison has gone into; I merely point out that we, as constructors, take into account that element of construction which he, as a mathematician, is not permitted to include. The question of dome construction is interesting, again, in view of the fact that there are two distinct modes of such practical design, both different from the theoretical dome of Mr. Denison's calculations. There is the dome of rings; and the dome of ribs; while the dome of the mathematician is a dome of unbonded voussoirs. In the dome of rings each course is bonded throughout by dowels or otherwise, that is, horizontally; while the dome of ribs is similarly bonded vertically, the spandrils being filled in with light material for the sake of covering in the dome with as little weight as possible to disturb the equilibrium of the ribs. These two principles are both worthy of theoretical study, but the subject is too complex and too large to be entered upon at present; neither should I consider myself competent to enter upon the discussion with any confidence; but I dare say Mr. Denison will agree with me in thinking both these questions to be, to us as architects, of the utmost importance. I join most cordially in asking the meeting to offer its best thanks to the lecturer for his paper.

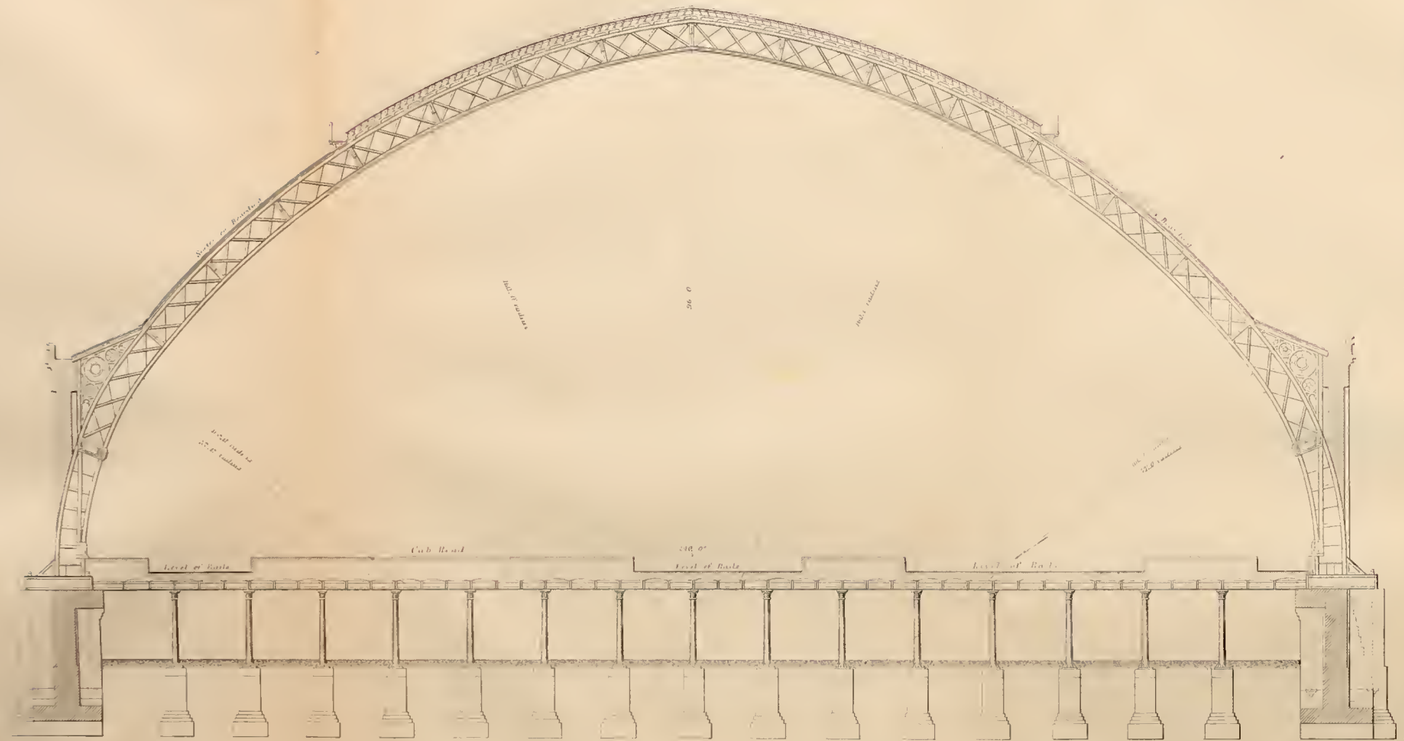
Mr. PENROSE.—I would ask Mr. Denison whether in speaking of the rib construction *versus* the uniform shell dome, he meant such a construction as that each rib is a perfect lune?

Mr. DENISON.—I am glad Mr. Penrose has asked that question. What I meant to say was—these ribs in the Pantheon are an approximation to lunes themselves, or perhaps are lunes exactly up to the 'eye,' where they stop. In a former discussion here it was assumed that domes should be built with what are distinctly called 'ribs' like arches, and not ribs and rings like those of the Pantheon, which is a good and right construction, except that you lose the benefit of bonding between those ribs, where the spaces are occupied by panels which are much thinner, but that is enormously excessive in stability and thickness. Mr. Papworth made a remark upon the dome of St. Vitale at Ravenna, and that of St. Sophia, and thought that I spoke in depreciation of them. What I said was, that both of these being segmental in construction they do not afford grounds for coming to any other conclusion than that very thin segmental domes will stand, which I presume is known to every man who has ever turned a flat dome over a well. But a segmental dome is no precedent for drawing accurate conclusions as to a complete hemisphere. Then Mr. Penrose and Professor Kerr spoke about bond and friction. I said that in treating this mathematically we must cut the dome up into lunes, and throw over the benefit of friction and bonding. But I omitted to add, that on the other hand I set off that against the assumption that the stones will not crush with the line of pressure going close to the edges, as you will find when you come to read the paper. A gentleman asked a question about the pressure below the limits of what I call "natural stability," which goes down to 52° without any thickness at all; in a hemisphere with a thickness of a 25th of the radius, the natural stability is carried to 68°, and the reason I call it natural stability is that if the dome were tied there it would stand. The distinction between natural and other stability is, that when you get below (say) 68° you must either have a tie or take into account the pressure inwards of the parts below, for the explanation of which I must refer to the paper. Mr. Nash spoke about the natural sagacity which is required on the part of architects, being better than mathematics for coming to a conclusion on these subjects. I quite agree with him that there is ample scope for natural sagacity in managing the bonding and general construction. But Mr. Nash must remember that the natural sagacity of the profession has been exercised on this subject all these years—I may say for centuries—and yet you have never been able to come to any

THE ST PANCRAS STATION.

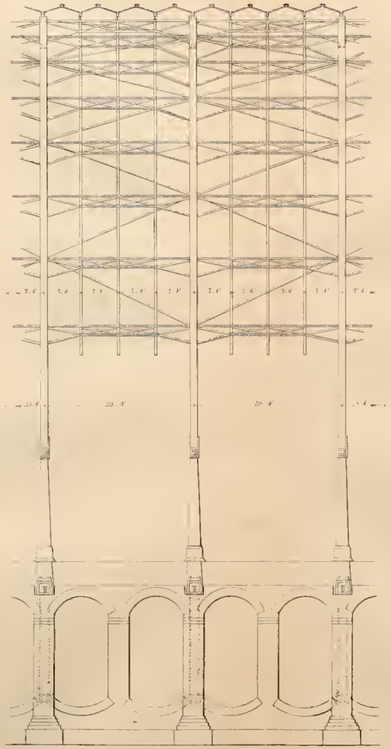
MIDLAND RAILWAY.

Fig 1



ELEVATION.

Fig. 2.

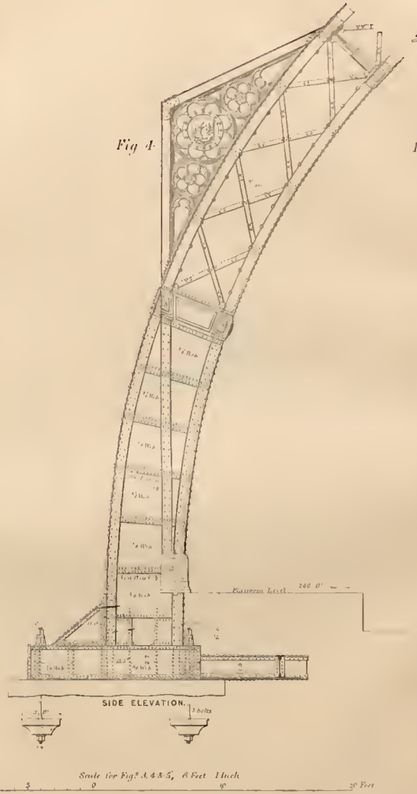


LONGITUDINAL SECTION.

Fig. 3.

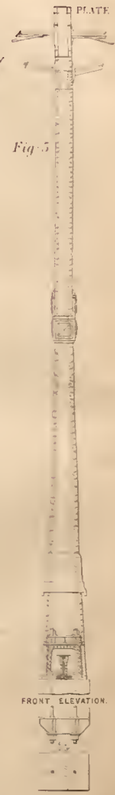
BACK ELEVATION.

Fig 4.



SIDE ELEVATION.

Fig. 5.



FRONT ELEVATION.

PLATE

THE ST PANCRAS STATION.

MIDLAND RAILWAY.

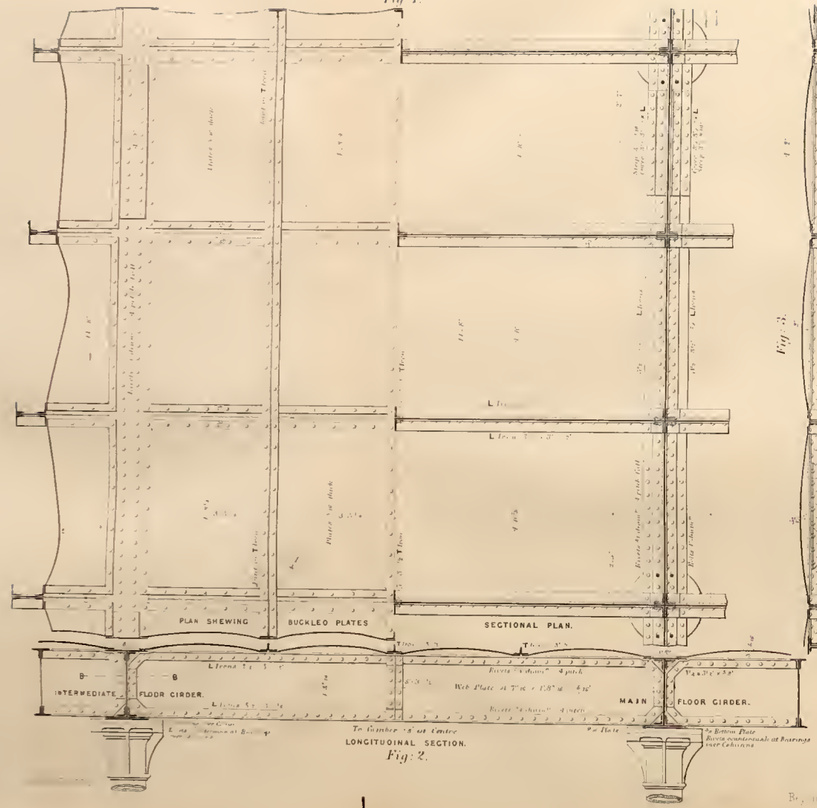


Fig. 1.

Fig. 2.

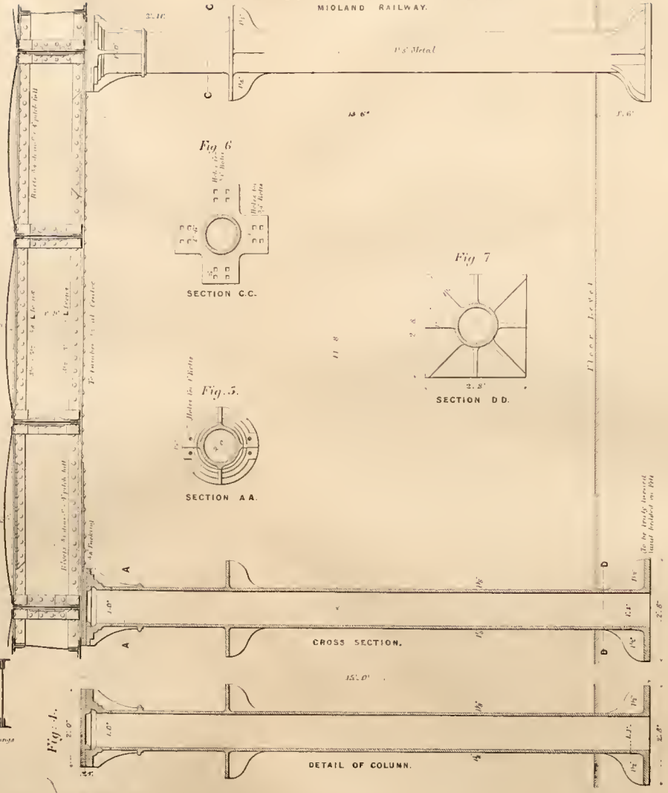


Fig. 3.

Fig. 4.

Fig. 6

Fig. 5.

Fig. 7

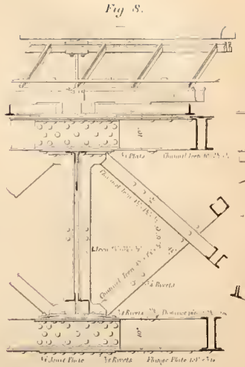


Fig. 8.

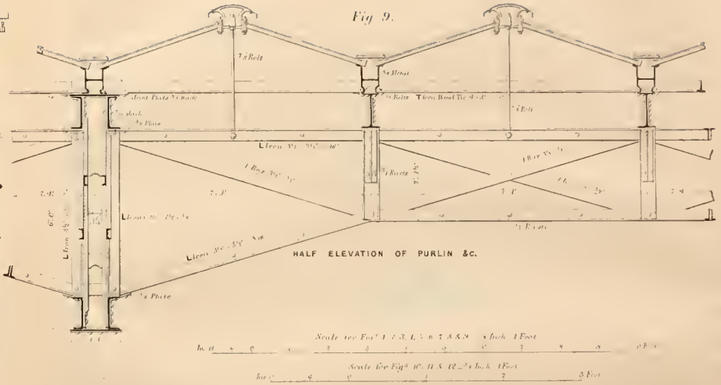


Fig. 9.

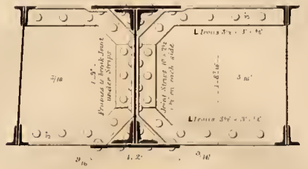


Fig. 10.

Fig. 11

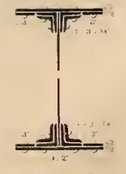


Fig. 12.

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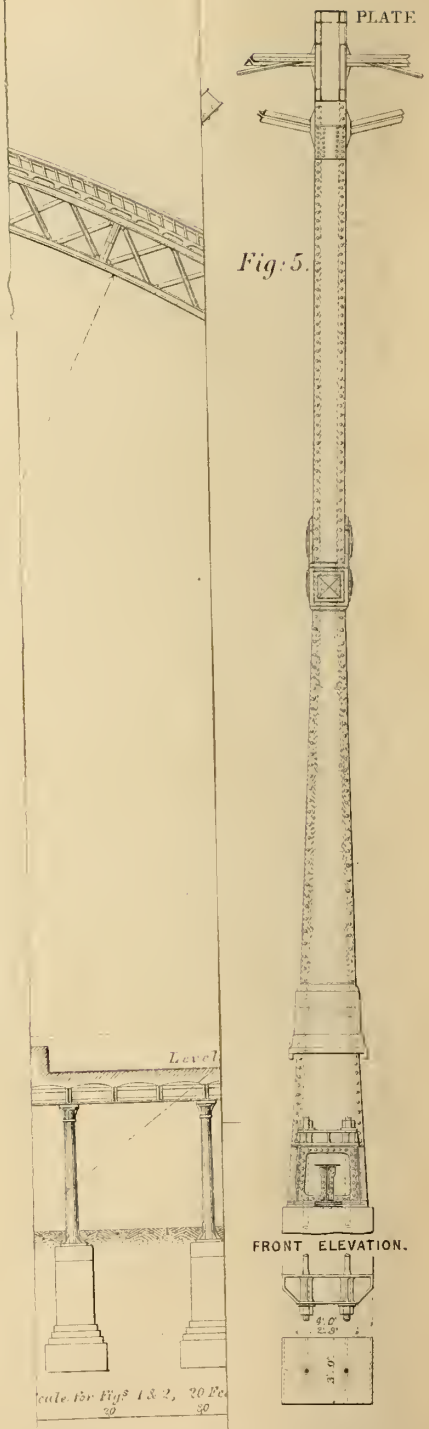
PLATE

Fig: 5.



THES CASTLE ST HOLBORN

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, 20th February, 1871, Thos. H. Wyatt, President, in the Chair, the following Paper was read:—

ON THE ROOF OF ST. PANCRAS STATION.

By W. H. Barlow, Esq., C.E.

The large arch which constitutes the truss adopted in the St. Pancras Station owes its origin to the floor beneath it. The level of the rails being of a sufficient height above the adjoining streets, it was decided to utilize, for traffic purposes, the whole of the area beneath the Station; and in order to economise the space to the utmost, it was determined to employ iron columns and girders instead of brick piers and arches to support the platforms and rails of the passenger station. This decision, together with the manifest advantage of having the entire area of the station free from obstruction, gave rise to the particular construction of roof adopted.

For it became obvious that, if intermediate columns were employed, they must be carried down through the lower floor, be about 60 feet in length, and of much larger diameter than the rest of the columns under the station. This would have necessitated the employment of different patterns in the girders, cross girders, and in the plating of the lower floor, and have increased the price per ton for that portion of the ironwork, besides interfering with the economical distribution of the space. Moreover, these columns must have carried large areas of roofing in addition to the flooring, involving a greatly increased weight on the foundations, which must have been enlarged accordingly; and as some of them would necessarily have been placed on the tunnel of the St. Pancras branch, which runs under the station, special means and increased expense would have been required to carry the imposed weight at those places.

On the other hand, it was seen that the floor girders across the station formed a ready-made tie sufficient for an arched roof crossing the station in one span; all that was required to obtain a roof of this construction being the arch or upper member of the truss, of which the floor girders would form the lower member. There was a third feature in the case. In iron roofs as usually constructed, the depth of the principal is about one-fifth of the span; but here, by adopting one arch extending across the station, the height from the tie beneath the rails to the crown of the arch became the effective depth of the truss; and this height being about two-fifths of the span, all the horizontal strains arising from the dead weight of the roof, its covering, and accumulations of snow, &c., would be about the same in the arch of 240 feet span, with an effective depth of truss of 100 feet, as in an ordinary truss of 120 feet span with a depth of 24 feet. Excepting, therefore, such additions as might be necessary for retaining the form and figure of the arch, the actual sectional area at the crown, and for about two-thirds of the entire arch, did not require to be greater than in an ordinary truss of 120 feet span. There were several other advantages belonging to the arch,—one being that as the weight of the roof was carried at the floor line, and did not rest on the tops of the walls, there was no necessity to make the side walls thicker, for not only was the weight on the tops of the walls avoided, but also the racking motion from the expansion and contraction of an ordinary roof, which, though it may be mitigated, is not prevented, by the use of roller-frames at the feet of the principals and appliances of a like nature. It was

also apparent, that the arch might be made of rivetted plate ironwork like that of an ordinary railway bridge, and that the expense attending the use of forged and wrought work as in ordinary roofs would be avoided, including the screw cutting, gibs and cotters, welding, and similar costly workmanship. Again, as to the question of the expansion and contraction of the arched roof, the ties being beneath the ballast, the temperature would vary so little, that no provision would be necessary; and for the arched part of the roof, which would alone be subject to appreciable change, the only effect would be a slight rise or fall in the crown.

All the arrangements of roller-frames or slings, required in ordinary roofs to provide for the effect of variations of temperature, would, therefore, be avoided by the adoption of the arch; and lastly, the adoption of a single arch would not only save the cost of the columns and their foundations, but also that of the longitudinal girder required to connect them at their upper extremities, with a valley drain between the roofs, and vertical drain pipes, and other provisions for taking off the water from the area, between the centre lines of the two roofs, which would have been about two acres in extent.

All these circumstances tending to favour the idea of one arch across the station, the remaining question was, what depth and form of rib, and what additional material, must be employed to make an arch sufficient to retain its form under all conditions of stress arising from its own weight, from snow, and from heavy gales of wind. The results arrived at on this subject, partly by calculation and partly by experiment, were—

1st. That the depth of the rib must be sufficient to contain all the lines of pressure generated by the dead load, by snow, and by the pressure of the wind;

2nd. That the sectional area of the metal should be sufficient to sustain the whole stress without producing a strain on the iron exceeding $3\frac{1}{2}$ tons per square inch.

3rd. That the arch should be rivetted together with proper joint-plates throughout, so as to give it the advantages of complete continuity.

The probable additional cost of principals so constructed, of 240 feet span, as compared with principals of two spans of 120 feet and their columns, was estimated at about £6,000. Notwithstanding this, the importance attached by the Directors and the General Manager to obtaining perfect freedom in the use of the whole area of the station for traffic purposes, unembarrassed by columns or other impediments, was such, that instructions were given for an arch in one clear span.

The total area roofed in is 18,822 square yards. The distance between the side walls is 245 ft. 6 in., and the clear space of the roof 240 feet.

The main ribs are 29 ft. 4 in. from centre to centre, except at the two ends, where additional ribs are put in to carry the gables or screen ends.

The arch is made slightly pointed at the top; firstly, because it was considered that this form possessed some advantage in resisting the lateral action of the wind; and secondly, because it was considered to have a better architectural effect, by giving a defined apex to the interior of the roof.

The radius of curvature is diminished at the haunches, to give increased head room near the walls.

Description of the Roof.

The main ribs or principals are made of channel-iron and plate-iron, and are 6 feet deep, or one-fortieth of the clear span. The rib between the walls is of open work, but the extremities of the principals in the walls are of solid plates.

		Tons.	cwts.
The weight of the feet or pedestals is 9 tons 18 cwt. × 2	= ...	19	16
And of the open-work, extending from wall to wall		35	0
Thus the total weight of each rib is		54	16

The cost of each rib is as follows :—

	£	s.	d.
Wrought ironwork in rib, 54 tons 16 cwt., at £18. 10s. ...	1,013	16	0
Four holding-down bolts	49	0	0
Four anchorage castings	24	12	0
Two moulded bases	12	8	0
Two ornamental spandril frames	32	8	0
	£1,132	4	0

The erection of the roof was effected by two large timber stages, each made in three divisions, so that each part of either stage could be moved separately. These stages were designed by the Butterley Company, who were the contractors for the roofing and for the lower floor, Mr. (now Sir) G. J. N. Alleyne being the manager. The stages were 40 feet in width, of great strength and solidity, and contained about 25,000 cubic feet of timber and 80 tons of ironwork. The weight of each stage was about 580 tons, and with two ribs on it, the weight on the floor-girders where it stood, including men and apparatus, was about 650 tons. The passage of these two stages, which moved on wheels, along the floor of the building, constituted a good test of the strength of that portion of the work.

The process of erecting was as follows: the two lower portions or the feet of the ribs were first set temporarily in position, the brickwork underneath them being kept about 3 feet below its intended height. The feet were then accurately adjusted by timber-packing and wedges, and rivetted to the ends of the floor-girders; after which the brickwork was carried up in blue Staffordshire bricks set in Portland cement, and the whole secured to the under-side of the ironwork, the timber-packings being removed as the brickwork proceeded.

The open work of the main ribs was commenced from the extremities on each side, in divisions of about 18 feet in length, and these were placed temporarily together, supported by the staging, until all the pieces were in position. The whole was then adjusted for line and level, and rivetted together with the purlins and other ironwork.

The time required for putting up the pieces and rivetting, after the feet were fixed, was six days for each rib, and the last fourteen principals were erected in seventeen weeks, including delays from weather, and occasionally failure in the supply of materials and other causes. The ironwork was lifted by an ingeniously contrived engine, which worked ropes to derricks placed on the stages. The supports were adjustable on the stage. Special arrangements were employed to secure the line, form, and level of the work; and, the whole of the ironwork having been fitted at the Butterley Works, it was put together without difficulty. The greatest depression of any rib when the centre was struck was only $\frac{1}{4}$ of an inch, and the average was $\frac{3}{16}$ of an inch.

The contract provided for testing the roof; but the extreme stiffness of the work, and the unavoidable tests to which it was from time to time subjected during erection, were sufficient to show that no formal testing was necessary. In consequence of a delay in obtaining face-bricks for the side walls, a considerable numbor of ribs were erected, boarded, slated, and glazed before the side walls were built, and in that state the roof endured several gales of wind, one of which was unusually heavy, without the slightest visible movement. The lines of the roof are remarkably well preserved.

Strength of the Roof.

It will be observed, that the construction of the roof involves the problem of the continuous elastic arch, so constructed as to be capable of retaining its own form without any intermediate connections with the tie, or any aid from spandrils.

With the view of ensuring an ample margin for safety, it was considered expedient to adopt a low rate of pressure upon the metal, with a large assumed weight acting in addition to the weight of the principal. With this view, and to remove all doubt on the question of strength, the arch was designed so as to be capable of bearing an assumed load of 70 lbs. per square foot measured on plan, in addition to the weight of the principals, with a stress on the metal not exceeding $3\frac{1}{2}$ tons per square inch; or, what amounted to about the same thing, a load of 56 lbs. per square foot, with a stress of 3 tons per square inch. Of the 54 tons 16 cwt., the weight of the rib, a portion belongs to the connecting medium with the ties; excluding this portion, the weight of the rib is as follows:—

	Tons.
The open-arched part between the springings	35
The feet or pedestals, 9 tons 10 cwt. each ... ... =	19
	—
	—

The surface carried by the arched portion of the rib is 240 feet × 29 feet 4 in. ... ... = 7,040 square feet

	Tons.
And with the assumed weight of 70 lbs. per foot, the assumed load is	
7,040 × 70 lbs. ... ... =	220
And weight of arch ... ... =	35
	255

The line of pressure forms an angle of 55° with the horizontal at the springing, and therefore the pressures are—

	Tons.
At the springing	155
And at the crown	89

The sectional area of the rib is 46 square inches; viz., 23 square inches in the upper flange, and 23 square inches in the lower flange; so that the stress on the metal with the assumed weight of 70 lbs. per square foot, is—

	Tons.
At the springing	3·37 per square inch.
And at the crown	1·94 „

Experience has proved that in large roof trusses of the ordinary form, the strains generated by an assumed load of 56 lbs. per foot, in addition to the weight of the principal, may be from 4 tons to 5 tons in compression, and from 7 tons to 8 tons in tension, without exceeding the limits of safety. The reason for adopting so low a pressure at St. Pancras was that, in an arch of this form, and especially under the lateral action of wind, the line of pressure deviates more or less from the centre of gravity of the section. The effect of such deviation is to throw more pressure on one member of the rib than on the other; but the amount of the difference so arising is controlled and modified by the depth and stiffness of the rib in resisting flexure, and also by the extent to which the channel-iron cross-bracing causes the pressures acting on one member of the rib to be transmitted to the other.

The experience derived from what may be termed involuntary tests during the erection of the ribs, and the great stiffness and almost total absence of deflection or disturbance of any kind which the roof exhibits, point to the conclusion that the strength of the structure is in excess of what was needed.

It will be observed, that although the roof is independent of the side walls, in so far that it does not rest upon them, yet the weight of the side walls taken in connection with the manner in which the pedestals or feet of the principals are built in, contributes to the strength of the roof, by giving stiffness at the springing.

Since this roof was constructed, two valuable papers have been published on the continuous elastic arch, one by M. Goudard, at the Institution of Civil Engineers, and the other by Mr. W. Airey, B.A., in both of which the theoretical view of the subject is fully elucidated.

Cost of the Roof.

The roof as designed had twenty-four main ribs, and one gable or screen at the northern end. The southern end was intended to terminate against the walls, in the same way as the roofs of the Cannon Street and the Charing Cross Stations. But the acceptance of Mr. Gilbert Scott's design for the station offices and hotel led to this arrangement being departed from. In the original design the hotel was carried over the upper portion of the southern range of station offices; but as it was feared the steam and smoke of the engines would find entrance into the hotel windows, Mr. Scott planned a second gable and screen for the southern end, so as to separate the passenger station from the hotel buildings. This second screen involved an additional main rib, and to this extent the author's original design has been departed from.

The cost of the roof as it stands in the finally settled accounts is as follows:—

	£.
For the twenty-four main ribs with foundation bolts, castings for ditto, ornamental spandrils, and moulded basis, &c.	27,187
For the covering, including plate-glass, lead-work, purlins, intermediate ribs, wind-ties, gutters, ventilators, gangway, &c.	26,296
Total cost of roof, excluding screens	£53,483
For the north gable	7,375
For the additional main rib, spandrils, &c., at the south end ...	1,132
For the southern gable	7,375
	£8,507

The area within the walls measured on plan is 169,400 feet superficial, and the following statement exhibits the cost per square of 100 feet superficial:—

	£	s.
For the twenty-four principals or main ribs	16	1
For the covering, including purlins, &c.	15	10
Total cost of roof, excluding screens	31	11
The additional cost per square of the north screen	4	7
The additional cost per square of the extra rib and south screen ...	5	0

In conclusion, it may be desirable to say a few words on the coloring adopted.

There were two questions involved in it, one being the best coloring considered as a question of

ornament, the other being the best color in respect of its permanency, having regard to the uses for which the building is intended.

Had it not been that the roof in question was for the special purpose of a Railway Station, the Author would have endeavoured to select colors solely with a view to the best effect in ornamentation, but he had observed in the roofs of Railway Stations, that the steam of the engines condensed on the metal, especially about rivets and other projecting parts, and that the condensed steam ran down in small streaks, which became stained by the smoke and dust of the station.

This effect takes place on the ironwork but not on the woodwork, which is not so good a conductor of heat, and it was therefore thought that however agreeable the appearance might have been rendered in the beginning by light and ornamental coloring, yet that this appearance would have been rapidly destroyed from the operation of the causes above-mentioned; or otherwise maintained at the cost of frequent repainting. The Author also found that there was a great diversity of opinion as to what colors should be used, even looking at the question from a purely æsthetical point of view.

Considering on the one hand the possibility of arriving at a wrong conclusion as to the best artistic effect, and on the other the probable rapid disfigurement of the work from the causes above referred to, it was ultimately decided to employ French white for the woodwork, and chocolate color for the whole of the iron; which colors, so far as experience has extended, appear to possess the requisite quality of endurance when applied to the respective materials of wood and iron.

The PRESIDENT.—It is, I am sure, hardly necessary for me to ask you to say how deeply we are indebted to Mr. Barlow for his kindness in devoting an evening to us. When we think of his numerous engagements, we cannot but sympathize with this proof of his interest and co-operation on behalf of the Institute: on that score alone he has earned our best thanks. But we may congratulate him upon the accomplishment of one of the most important and interesting works of modern time. It has always struck me that one great merit of this very ingenious structure, beyond its comparative economy of cost, is the fact of Mr. Barlow having grappled with the difficulty of one unbroken arch, and looking at this roof, there can be no question as to the great benefit of one arch only over that wide space. The fact of the tie rods being enclosed in the ballast and concrete, and thus avoiding the effects of expansion and contraction, is one well worthy of mention: whatever expansion there may be, will be only upon the truss vertically. I shall be glad now to hear any observations that may be offered on this very interesting subject.

Mr. E. M. BARRY, Fellow.—We are especially obliged to Mr. Barlow for coming down to describe his very interesting roof, and we are the more indebted to him because he is not a member of the Institute, although he holds a high position in the Institution of Civil Engineers, among those who, in our own times, have done such wonderful works in the advancement of science. But we do not always find engineering works carried out with that desire to render them striking in an architectural sense, which Mr. Barlow seems to have felt on this occasion. I was much struck with the fact of the pointed arch having been adopted, and irrespective of any constructive advantages, one of which I apprehend would be throwing off the rain from the centre of the roof, it seems to have been with a view to architectural effect. I was very glad to hear that from a member of the engineering body, who some of us may think have been too much accustomed to carry out these great works without thinking of their architectural effect. I think the Midland Station altogether is one of the most admirable and remarkable works of this age of railway engineering, and we are much indebted to Mr. Barlow for giving us so clear an account of it.

Professor DONALDSON, P.P., Hon. Sec. For. Cor.—I had hoped that some one more experienced

in engineering than myself would have risen to follow up what has fallen from the previous speaker; for we cannot fail, all of us, to appreciate, not only the beauty, but the science displayed in this remarkable work. You will recollect, Sir, that when I returned from abroad, about two years ago, after a lengthened journey, I was so struck by the extraordinary construction of this work, and by the ingenuity and skill with which it was designed and executed, that I ventured to call your attention to it in a slight paper in this room. When we consider the difficulties to be overcome, looking at this section, we cannot but regard this unbroken space of 240 feet as one of the most ingenious works of the age, and Mr. Barlow has addressed himself to the task in a way that must command our highest admiration, and has led to the solution of a difficult problem in connection with arched roofs of great magnitude. Mr. Barlow has mentioned one circumstance with respect to the colour in which this roof has been painted, and the reasons which induced him to adopt a dark tint. In the discussion of this subject at the Institution of Civil Engineers, exception was taken to that colour, as being heavy and detrimental to the effect of the building. My own impression is that Mr. Barlow was right. If the roof had been painted of a light colour instead of a dark one, the whole effect of magnitude and distance would have been lost. One would have had no idea of its vastness, nor would one have imagined it to be so lofty as it is. I perfectly agree with Mr. Barlow that he has adopted the colour best adapted for this station. The whole structural effect of the building is as light and airy and fanciful as anyone can conceive. Yet the truth is, Mr. Barlow has so well combined all the parts of the station, that there is rigidity and strength enough to resist any forces that can come upon it. The portion of the construction at the haunches, when I saw it being erected was to me a marvel, and I could not conceive how it was possible for this arch to stand without something like an abutment to resist the thrust at this point. This is a most valuable proposition to us as architects, and opens our minds to a wide sphere of construction. I feel that we are very much indebted to Mr. Barlow for coming amongst us with this interesting problem solved, and I beg to propose that we acknowledge his kindness by a sincere vote of thanks.

Mr. C. Barry, Fellow.—I beg very cordially to second that, and to join my thanks with others for the information Mr. Barlow has given us. This paper is so full of matter, and so pregnant with details, that every statement made in it will deserve careful study when it comes to be printed. I hope illustrations of the diagrams before us will accompany the paper, as without them it will not be easy for us to understand and to follow the calculations he has been good enough to give us; and then I shall regard this as one of the most valuable papers we have on record. There is one point of interest which Mr. Barlow only touched upon without entering into particulars; but I have no doubt he will be able to tell us whether, from the action of the wind on one side of this large expanse of roof, to which he alluded as a subject of calculation, any lateral strain or distortion in any part of the roof has been observed, resulting from the wind impinging upon it. I tried to follow Mr. Barlow's details as to another point of great importance, viz., those relating to cost. I gathered that the cost of this great work was something like £ 70,000., or about £ 30. per square. That struck me as an extremely moderate cost for any roof of like importance, and I dare say Mr. Barlow had in his mind, when he considered the cost he was about to incur, what was the comparative cost of other large roofs, as well as the advantages (and they seem many) of one span of 240 feet rather than two of 120 feet. If, in addition to the valuable information he has given, he could supplement it by furnishing the cost per square of other similar roofs, it would add to the interest of the paper and the discussion which will now follow upon it. I should be glad if he can tell us the cost of the roof of the Central Station at Milan. I fancy it cannot have been so large as this; but it struck me as being one of the most graceful and elegant roofs of large span I have ever seen. It was an iron roof, and I am under the

impression it has the same feature of being supported from the ground. I will conclude by cordially seconding the vote of thanks to Mr. Barlow.

Mr. E. L'ANSON, Vice-President.—I join in looking upon this as, at present, the climax of great works of this character. I believe the roof of the Strasbourg Railway Station, at Paris, was the first example of a large span: that was followed by the roof of the Great Northern Station at King's Cross, the success of which was not eminent, and that again was succeeded by Mr. Hawkshaw's roofs at Charing Cross and Cannon Street, and lastly the climax was reached in Mr. Barlow's roof. [The PRESIDENT. And the Liverpool roof]. This is the largest and grandest work of the kind known to me. I would ask whether there is anything more in the construction than meets the eye of the uninitiated, and whether, in fact, it is what it appears to be, an arch? Professor Donaldson speaks of it as being fairy-like and aërial in appearance—those effects are not arrived at without combinations of thought, the principles of which it would be satisfactory to follow. Looking at the section of the roof-ribs, the sectional area of the top and bottom flanges of the girders (if such they be), or arch ribs, is the same, and I suppose the tension and compression upon both is therefore taken to be the same. I would ask Mr. Barlow if that is the case, whether, upon the top and bottom flange of these lattice ribs, the strain is throughout the same. Then I would ask whether we can look upon this at all as in the nature of the construction of an arch. I apprehend if it were a free arch the haunches would require more loading than is shown on the transverse section; therefore it is something more, I presume, than a free arch would be, though composed of stone voussoirs. Although so light in appearance, it seems so substantial and adequate to the work it has to perform, that it is not difficult to appreciate the careful investigation necessary in order to calculate the form of such an arch-rib. Some years ago I was engaged in inquiring into the adequacy of an arch-formed construction of iron, and on that occasion I took the liberty of asking Mr. Barlow's opinion, and I think he then said that the arched construction which I took to him to look at was, though in form an arch, nothing in fact but a girder. I would ask him if this is a stiff girder, or in principle an arch, or whether there is anything more in the construction, from which we who are not initiated in wrought iron might take an example.

Mr. EDWARD HALL, Visitor, said:—During the construction of the Exhibition building in 1851, you will recollect a great deal was said as to the desirability of covering the main portion of the building, or so-called *nave*, with a roof of similar construction to that of the transept. The difficulty then supposed was the absence of sufficient means of resisting the thrust of the arch. The arch, or principal of the transept, was composed of timber. However, subsequent to the adoption of the structural arrangements, it was said that experiments had been tried with one of the transept-principals, when no thrust whatever was found to be exerted; therefore, if it had not been for the pressure of time, there is no doubt the covering of the "nave" would have been of the same description as that of the transept. It having been concluded that an arch-form of covering for the "nave" of a similar building was the proper thing for effect, the Crystal Palace at Sydenham (as regards "nave" *as well as* transepts), was roofed over in that manner. But, there, the principal was composed of iron, with diagonal bracing filling in the space between the flanges, or outer and inside concentric curves; that is to say, the construction of the arch itself was similar to that of this station-roof: however, the ribs have neither tie nor abutment. The whole of any thrust is absorbed in the space, between *extrados* and intrados, and dies away at or above the level of the springing. Therefore I would beg to ask Mr. Barlow whether, in the station-roof, there is thrust to be resisted; whether, in other words, the tie is essential, or whether it is simply one of those supplementary or precautionary provisions which an engineer would, with propriety, introduce, notwithstanding that he had good reason to suppose that no demand would be made upon the structural feature, for duty to be performed.

Mr. C. FOWLER, Fellow.—I venture to put one question to Mr. Barlow in an artistic view of the matter, which may be interesting to us, that is as to the radii of the curvature of the arch. Mr. Barlow mentioned that the radius was smaller at the springing, which we see, but he did not give us the proportions of the radii. Mr. Barlow mentions in his paper that the sectional area of the upper and lower flanges is the same throughout. Perhaps he will kindly state whether he considers the strain is the same throughout, for I suppose this arch must be considered structurally as a girder, or rather two girders united at the apex, and forming with the tie at the springing a triangle; and I imagine the strain is not the same throughout. But probably Mr. Barlow thought that in the somewhat novel application of the principle of this construction, it was desirable to be on the safe side as regards strength. He may have also considered that for manufacturing purposes it was better to continue the same size of flange, though it was not absolutely necessary.

Professor KERR, Fellow.—I have always thought the design of Mr. Barlow for this roof not only one of the remarkable events of the age in engineering, but one of the most instructive lessons as regards the principles involved, ever laid before us. Most of us recollect the time when, in connection with the Exhibition building in 1851, we were struck with surprise, no less than admiration, by the simple notion of Sir Joseph Paxton for the peculiar construction then adopted. The simplicity of the idea was so extraordinary that it at once took the fancy, not only of the public, but to a great extent of scientific men, as a typical novelty, and I am bound to say, without desiring to indulge in flattery, that in my judgment this seems to be in another field, and perhaps in a more scientific way, an equally typical novelty in the way of introducing a new constructive principle. Any one, even amongst ourselves as architects, who looks at the section before us, will observe at a glance the extreme simplicity which is arrived at; and this, as we know, might be arrived at by one of two methods. On the one hand this may be a happy conception, arising from what is called a stroke of genius; on the other, it is the elaboration of scientific study, which may have resulted in such simplicity. In either case we may be permitted to accord to the designer our great admiration of the skill with which he has accomplished the solution of his problem. The question of the adoption of what is called the pointed arch is an interesting one to us. Mr. Barlow says he adopted that form, to some extent, on architectural considerations. We must not, perhaps, accept his phraseology in the precise sense in which we are accustomed to apply it; but we may consider that there is a certain element of beauty involved in the pointed arch form, in this particular instance, which is well suited to the circumstances of the case. What Mr. Barlow says is, that he desired to have a ridge line, and we must all agree that in a structure of this kind there is here an idea of beauty worthy of consideration. The question has been asked by more than one gentleman, whether this roof is an arch or a beam. I will leave Mr. Barlow to answer that in his own way; but I take the liberty to remark, that, in one sense at least, Mr. Barlow fully appreciates the principle that it is an arch, by adopting the very form of which I am speaking. The structure may certainly be said to cease to be a beam when it is formed of two pointed ribs. Indeed, whether it is correct to designate such a structure as a beam in any sense I leave him to say; but we may take the opportunity of reflecting that an arch is not necessarily an arch of stone voussoirs. In fact, the idea of an arch of voussoirs stands at the end of the process of thought involved, not at the beginning. Even historically, the first form of arch consisted of two inclined stones meeting at the top, and from that simple form we find it gradually advancing through successive ages, till at last the semi-circular arch was fairly brought into use by the Romans. When, in the middle ages, the pointed arch was made the leading feature of architectural design, I am disposed to contend it was not in any sense as a further step beyond the arch of the Romans, but mainly on account of the circumstance that the pointed arch, being so much simpler, is so much stronger than the semi-circular arch, so that the

elegance of design, and consequent lightness, observed in the works of mediæval times could not have been accomplished with the semi-circle to such an extent as is shown in a thousand examples in the pointed arch. Therefore the designer proceeds upon strictly scientific ground, even if he claims no more, in giving to this arch the pointed form. We further see that the rib is divided into equal lengths; and these lengths are obviously voussoirs. They meet in radiating joints; and if these are rivetted together, it is simply upon the same principle on which we use the radiating principle in stone voussoirs, and, indeed, generally take particular care that these joints shall be, not only well connected by the mortar, but even rendered immovable by the insertion of dowels. I would ask Mr. Barlow to be kind enough to give us information on one point. I do not want to press him too closely upon questions of mathematical detail, but the drawing I see before me on the table (a theoretical diagram of the equilibrium of the arch) encourages me to ask what is the actual condition of this curve as regards the theoretical curve of equilibrium applying to the conditions of the roof. One cannot help seeing, first, that the arched rib is of equal depth throughout, and when we note that the flanges are also equal throughout, and that the strain at the top is two tons per inch, and at the bottom nearly three tons, this would show that it would be quite possible to introduce such a modification of the depth of the rib, or of the sectional areas of the flanges, as would suit this difference of strain. It would obviously, however, be a matter more of appearance than of economy, for in making the rib of equal depth throughout, or even in graduating the size of the flanges, the saving of iron would not pay for the trouble. Mr. Barlow may again be asked, as a matter of science, whether it has been necessary to accommodate the depth of the beam throughout to any conditions of equilibrium arising out of the accepted curve. One cannot help thinking, looking at that curve, that it is very nearly in itself a simple curve of equilibrium. It is not weak, in fact, we know; but the weak point, as regards scientific equilibrium, seems to be at the haunches. We should be wrong in supposing that the ornamental spandrils outside the rib at those points add materially to the strength of the rib, for though these additions happen to be placed at the weak points, yet it is obvious that they do not apply to the whole of the deficiency which one would be inclined to suggest at that particular point. The question of the scientific equilibrium of the curve would, I apprehend, again turn upon the point, whether at the haunches, the depth, or the sectional area ought to be increased to suit the conditions.

Another interesting point to us is this. Looking at the structure before us, how can it be decorated? We architects, of course, never lose sight of this particular question of art, how is structure to be decorated. The highest efforts of the architect are directed to the decoration, artistically, of the crude structure he builds scientifically. If we bear in mind the simple principles on which the present structure is designed, viz., that a curved rib consists of a top flange, though of complex form, and a bottom flange of similar form, and a latticed web between the flanges to keep them at a certain distance from each other, we perceive that, as the lattice work has no other function to serve than to preserve this element of depth, it is capable of being treated as a feature of decoration, with considerable confidence. Of course the simplest form of lattice work is that which is here represented; but it is competent for an architect, in designing a structure of that kind, to introduce other forms of perforation into a web, supposed to be primarily solid, than this simple diamond form, which is that of the usual lattice work. One might also give a certain special form to the top and bottom flanges, and then by filling in a perforated web as an ornamental frame, it seems to me that this singular structure could, with great facility, be brought into that condition of simple ornamentation which we observe in the best works of the early classic and mediæval times. For my own part I will say I am extremely gratified to be able to carry my admiration of this structure so far in that direction as I do. With regard to the only other point which I may mention, that of coloured decoration, I am afraid Mr. Barlow, as an engineer, would scarcely be

able to appreciate all the questions, which seem to us, as decorative artists, to be involved, more or less, on the mere mention of coloured decoration as applied to such a structure. The painting of the iron-work in chocolate, relieved by white, may suit structural purposes; but, of course, if some of our friends who are more engaged in the decorative element than others were to be requested to treat the work in a scientifically decorative manner, Mr. Barlow's principle would soon be left in the background. The appearance of the roof as it is, may be light, simple and graceful, and moreover agreeable; but I have no doubt that if it were treated in a more highly decorative manner, perhaps adapted to something else than a railway station, the structural elements are such as to admit of the iron-work being decorated most successfully.

Mr. T. MORRIS, Associate.—I would ask whether Mr. Barlow has treated the equilibration of this arch on the principle of the bow and string.

Mr. T. M. RICKMAN, Fellow.—We have hitherto forgotten to recognise the courteous and liberal manner in which Mr. Barlow permitted us to inspect the work during its progress. I would beg to ask what is the thickness of the glass in the roof; what is the extent of the rain-water piping; and, with regard to the floor which forms the tie, I would ask what weight per square or yard are the columns which carry that floor calculated to bear.

Mr. G. AITCHISON, Fellow.—I will venture to trouble Mr. Barlow with one or two questions. The arch appears to be divided into a certain number of pieces or voussoirs. I should be obliged if he will tell us whether the section of the iron-work increases from the apex down to the solid portion where it joins the wall? also, what strain there is on the tie, and if he has observed whether there has been any elongation or contraction of the tie from variation of temperature? I should also be glad to know what sort of bottom he has for the walls, and what weight per square foot he has on the foundations at the bottom of the concrete. He has mentioned that it was partly on æsthetic grounds that he made the roof pointed. When engineers have such problems to solve, viz., to roof over enormous spans, the question of shape may be purely statical, and it may be impossible they should deal with it as a question of beauty, because generally the difficulty is how the problem can be solved at all, and so far as the arch was pointed for the sake of construction no one can find fault, but on æsthetic grounds it is unfortunate. We know the pointed arch was originally the effect of necessity, and is one of the most hideous shapes that can possibly be found; therefore if Mr. Barlow could have avoided putting this point, I think any one would agree that it would have been a great improvement; in perspective all pointed arches give a bad curve. Professor Kerr has spoken of the ornamentation of engineering works. I am afraid when they come to be of large size, the engineer would rarely get much assistance from our profession, for where the engineer does arrive at beauty, it is where the laws of beauty coincide with the laws of force. I have seen many of these roofs of large span, some of which are very beautiful; and supposing we had any one who could design these large things ornamentally, the question whether economy could be sacrificed to ornament is one for the future to determine. We may hope, as men's minds expand, we shall find engineers in the future not only able to grapple with these large questions of science, but with the problems of beauty as well. In that case it may be a question whether it is not worth while to sacrifice a certain amount of money to make things more agreeable to the eye than they are at present. But it appears to me doubtful whether in our present state of knowledge and skill these large engineering works could be rendered more beautiful by any additional outlay of money, for it is doubtful whether any body possesses sufficient skill to know how beauty could be added to them.

Mr. C. F. HAYWARD, Fellow.—As the roof of the Great Northern Station at King's Cross has been referred to (in connection with that of the Crystal Palace transept) I may remind the meeting that

it was of wood, and that the depth, as well as the sectional area of the ribs, was remarkably small compared with the work before us, and with similar iron roofs. These ribs were formed of laminated timber; planks in layers, connected together by bolts and screws, and fixed up in sections. The form of the ribs is semi-circular, and they are stilted on piers and corbels a considerable height, and there are no ties. The failure of that roof has been rather the result of the material than of the construction. It appears to have been weak at the crown and at the haunches (though part of this was more apparent than real); yet had the material been iron, of which it is now re-constructed (on the same piers and of the same form) this would not have been the case. By using the pointed arch, thus accentuating the ridge line, the appearance of weakness at the crown, inevitable with a semi-circular form of rib, is avoided. I still consider it a very fine design, and one showing extreme lightness of section, with a span of 105 feet (or rather two spans of this width each), and very economical in construction, if not too much so. This timber roof may now be looked upon as a successful temporary covering, and one which served its purpose: means for a more substantial structure not having been placed at the architect's disposal. Even the common pale fence gates have served the entry to the cab-drive twenty years; and when a pupil I recollect seeing the first experimental rib, and learning the satisfactory results of the test weights applied to it. But we now see quite overshadowing it a roof capable of enclosing the two spans of this Great Northern roof, and more—a stupendous work, impossible to have been carried out in any other material than that of which it is composed. I would add my small tribute of thanks to Mr. Barlow for having favoured us with this description of his magnificent work at St. Pancras.

Mr. BARLOW, in reply upon the discussion, said—The questions put to me are rather numerous. I am not sure that I have been able to collect such accurate notes as to be able to answer them all completely, but I will do my best. In the first place, a question was put with reference to lateral movement arising from the wind, and I was asked whether we found any lateral movement from that cause. I may answer that we have found none whatever. I think it is extraordiuary not finding it, because in consequence of delay in the brick-work of the side walls we had to put up a good many of the ribs without the side walls, and in that condition they were exposed to gales of wind without the support that the side walls were intended to give them. The conclusion I came to is that we might have saved metal and have gone into lighter construction. The next question was as to comparative cost. There is something invidious about comparisons, and I don't know anything more so than in the cost of roofs. As a matter of fact, this roof is less costly per square than the Cannon Street and Charing Cross roofs. It is about the same price per square as the great roof just completed at Liverpool for the London and North Western Railway, the span being 220 feet. On the other hand, the roof at Birmingham, from 212 feet to 220 feet span, cost little more than half this, viz., £17. 6s. per square. It is difficult to reconcile these statements of cost, because it is governed by two circumstances. One is the character of the covering employed. In the case of the Charing Cross and Cannon Street roof, there is heavy boarding and heavy slating, all adding to the weight and cost, whereas the corrugated iron used at Birmingham is comparatively light and cheap. The market price of iron-work also varies a good deal. This was £18. 10s. per ton. The price paid for the iron-work of Charing Cross and Cannon Street was £24. 5s., and for the Birmingham station £17. 10s. With this variation in the price of the materials, which is the main element of cost, it is not possible to make a strict comparison, unless that part of the matter is taken into account. I have been asked about the Milan station roof. I have never seen it, and therefore cannot say anything about it. Then as to the form of the ribs and the area of the upper and lower flange, it is an arch in one sense and a girder in another sense. It involves the question of a continuous elastic arch, not in the nature of a stone arch, in which the resistances are all those of compression and none of tension. It is easy to separate the stones of an

arch, but it is not so in this case: the several divisions cannot be separated without breaking the material, because the joints are rivetted above and below, so that there is perfect continuity throughout, and it is impossible to produce flexure in one part without producing it in the other, so that it acts in the double capacity of an arch and a girder, or continuous elastic arch. It has been said that the appearance is that of weakness at the springing, and that in the appearance of the general design it is not seen how that apparent weakness is cured. I agree to this extent, that the line of pressure in this arch comes near the inside of the haunch at the springing, and tolerably near the crown at the top; therefore, assuming the arch to be free to move, the tendency would be for the haunches to go out and the crown to go down; but to remedy that we have got a completely solid piece of iron-work at the bottom, and that solid piece is connected with the brick-work of the wall, and though this section does not fully convey the idea of the work, it will be seen that the iron-work is so embedded in the brick-work that it could not move without the brick-work moving. I would correct the impression which seems to prevail that the tie was put in for the purposes of the roof; the fact is, the tie was decided upon before the roof was designed, and the tie gave rise to the roof itself being constructed in one large span. It has been asked whether there is any horizontal strain acting upon that tie. To that I would say, if there was nothing else to resist it there would be horizontal thrust of considerable amount; but there is more to resist it, therefore the tie has not much duty to perform, though I do not think the arch would be safe without it. One gentleman referred to the arch of the Exhibition building, and to the experiments shewing that the arch had no thrust. That could only have been in an arch of small span and considerable depth, because an arch of this span and depth, and having a proportion of depth of two-fifths of the span, would exert a large action of thrust, and require to be provided for. The Crystal Palace arch is an arch without a tie, and is supported high up above the ground; but, it will be recollected, that at the bottom of the arch there are two galleries and two columns, and these act in the nature of an abutment. As to the radii of curvature it was necessary for the purposes of the traffic to give head room at the sides, and therefore we were obliged to sharpen the curves there. Then again I was led to the conclusion that in a large arch of this sort, unless there was some indication where the crown of the arch was, the eye would be wandering about for the crown of the roof. A gentleman has referred to the arch at King's Cross. I concur in the opinion he expressed of the great advance that was made at that time in this kind of work. Being executed in wood it was one of the most remarkable structures of the period, and I believe myself that the failure was only the result of the natural decay of the timber. Had a more durable material been employed, or had the timber been preserved by some of the processes now in use, in my opinion that roof would have been in existence at the present day. In the suggestions made with respect to the ornamentation of these braces, it was assumed that they were solely for the purpose of keeping the upper and lower flanges apart. They have more duty to perform than that. The line of pressure in this arch varies according to the pressures coming upon it. Assuming a fall of snow to be on one side, followed by a gale of wind on that side, then the duty of the angle bracing it is to transfer the pressure, and in the event of the line of pressure falling between the two flanges, the pressure is communicated through the diagonals. It is important to maintain straight lines, to be of sufficient strength to perform that duty, providing for that condition, ornament upon it as may be deemed necessary.

I was asked to give some details with respect to the weight of the glass and the extent of the rain-water pipes, but I am unable to do so from memory. With regard to the weight which the floor is calculated to bear, the best test of that is the fact that the stages weighing 1300 tons were moved over every part of the floor, which is a heavier weight than if the whole building were filled

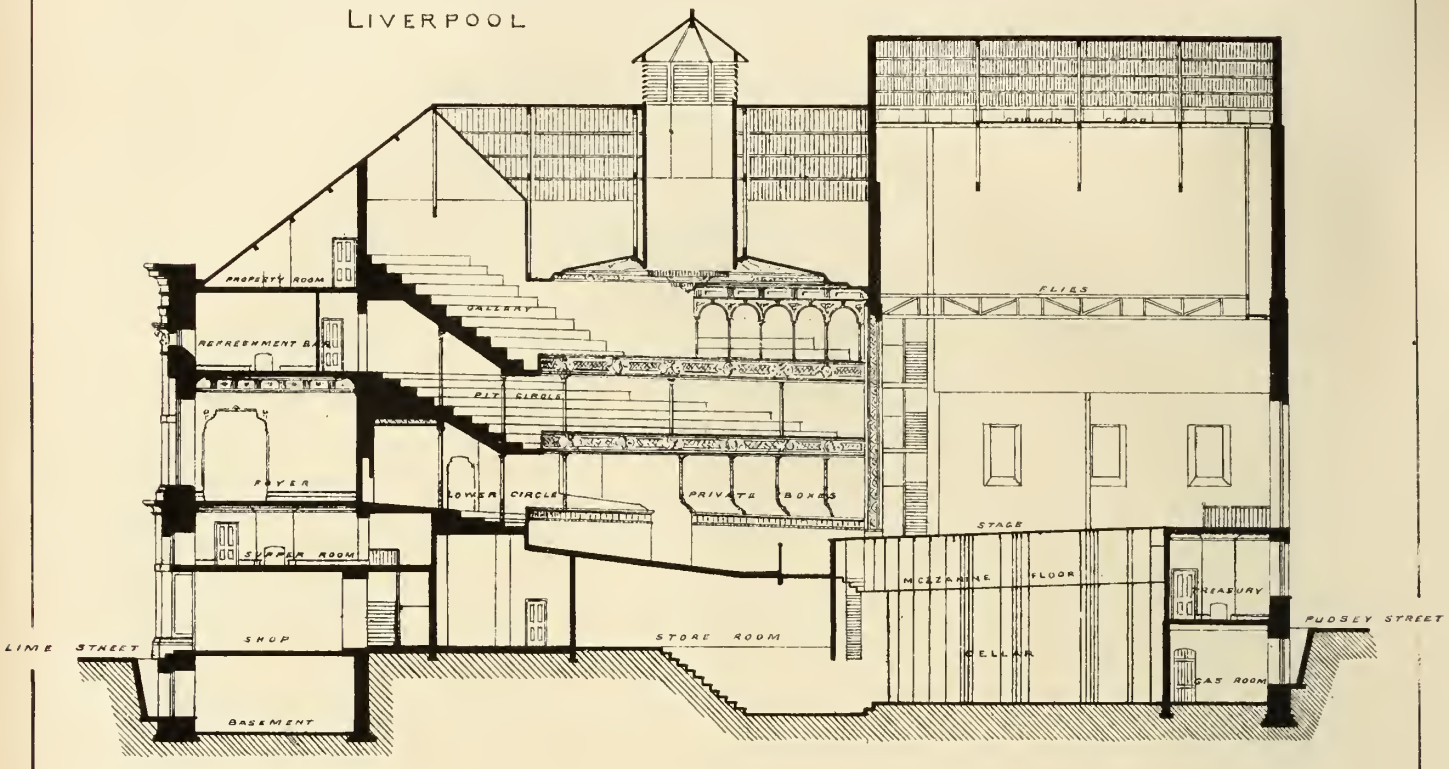
with locomotives. As to the connection of the floor girders they are all riveted together to the bottom of the rib. With regard to the section being the same throughout, it was suggested that it might have been of greater depth at the haunches and less at the crown. I agree that that would have been a proper thing to do where there is no wind to blow, and no snow to fall; but it is not the best form as I think when you have to deal with various pressures. The arch is subject to two pressures, viz. the vertical pressure and the tendency to disfigure the form, and it is to avoid the latter that the apparent excess of metal is placed in the crown of the arch, and it also enables the material to be put together at a less cost. Departure from an uniform size would have led to considerable cost, and I do not think it would have been attended with any advantages. I may mention that the spandrils are partly ornamental to fill up the gap. A gentleman asked whether any effect of elongation of the tie has been observed. If there has been any it is so small as not to have been visible, or else it is absorbed in the elastic action of the metal itself. With regard to the weight upon the foundations, these are on the London clay, and, as we all know, that is a curious material to deal with, and is subject to a weakness of its own; but in putting these foundations in we never allowed less than two tons per square foot. With respect to the remarks about the colouring of the roof, I will not enter into that question, as it is one rather out of the province of the engineer. I will only say that the great argument with me is that utility is the essence of ornamentation. I wanted to make the thing do its work, and I was obliged to let appearance take care of itself.

The PRESIDENT.—In rising once more to tender thanks in the name of the Institute to Mr. Barlow, I will make only one or two remarks. In the first place I would say, the fact that this marvellous roof has been constructed and placed in position with a deflection of only three-sixteenths of an inch is one which reflects great credit not only upon the mind which originated but upon the hands which executed it. One gentleman has alluded to the great desirability of the paper being accompanied by the illustrations that have been brought before us to-night. Mr. Barlow has conferred the same benefit upon the Institution of Civil Engineers as he has upon us, only going more fully into details, which were more of an engineering than an architectural character, and, as no doubt that paper will be illustrated by the drawings, we may hope through the favour of that Institution or of Mr. Barlow, that a copy of these excellent diagrams may accompany the paper when it appears in our Transactions.* I observed that Mr. Barlow did not dwell much upon the construction of the great stages made by the Butterley Company. I don't know whether he can bring his influence to bear in the way of procuring us a detailed account of these constructions. [Mr. BARLOW.—I have no doubt Sir, G. J. N. Alleyne will be happy to do so.] I will not enter into the question of the pointed arch decoration; in the absence of Mr. Ruskin, I should be bold were I to attempt that; but there is one circumstance which I cannot refrain from noticing; that is, the great harmony with which Mr. Barlow and Mr. Gilbert Scott have worked together in this matter in the characters of engineer and architect. I beg to tender to Mr. Barlow our cordial thanks for the trouble he has taken in making clear to us the principles of construction of this remarkable work.

The meeting then adjourned.

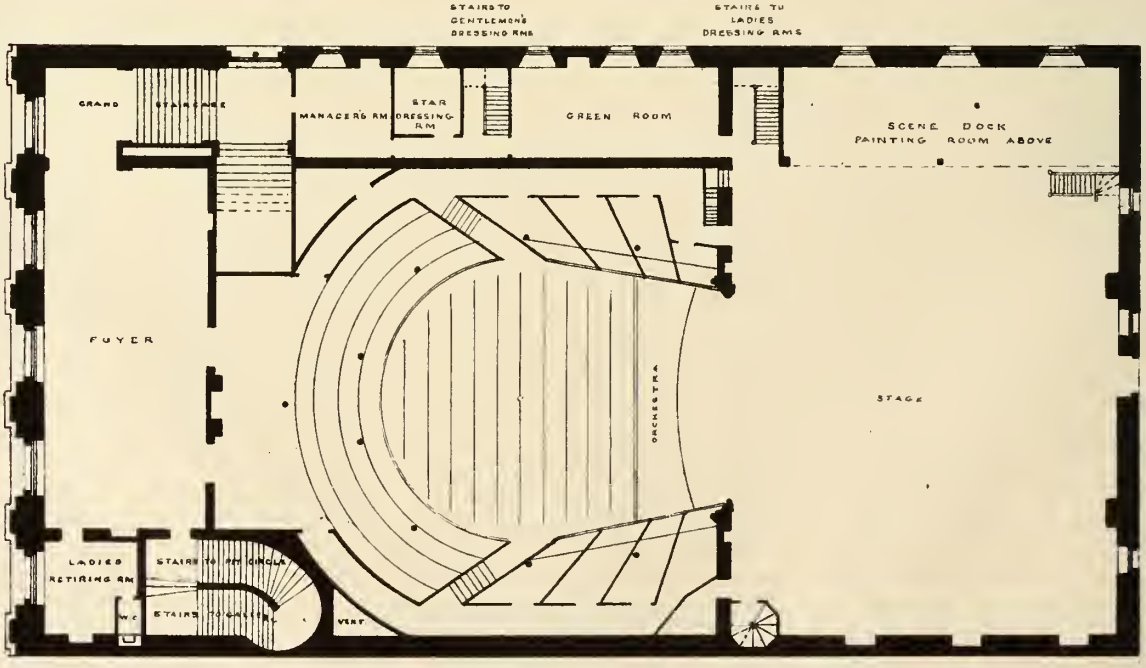
* By the courteous permission of the Institution of Civil Engineers, the illustrations appended to Mr. Barlow's Paper read before that Institution, have been reprinted for this Number of the R. I. B. A. Transctions.

ALEXANDRA THEATRE
LIVERPOOL



LONGITUDINAL SECTION

SCALE OF FEET



LOWER CIRCLE PLAN

Photo-Litho.d for the R.I.B.A. by Whiteman & Bass, London.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, 20th March, 1871, the following Paper was read—E. I'Anson, Vice-President, in the Chair:—

A DESCRIPTION OF THE ALEXANDRA THEATRE, OF LIVERPOOL, AND ON THE CONSTRUCTION OF THEATRES GENERALLY.

By Edward Salomons, Fellow.

I had originally intended that the title of this Paper should be "On the Construction of Theatres" only, but after further consideration I changed it to its present one, as I thought it would be more interesting to my fellow-members to have the description of a theatre I have built, for by that means, I could more practically illustrate my ideas on the subject generally. I thought also it would not be uninteresting to show some of the working drawings prepared for that purpose.

I shall as far as possible confine myself to such points as my especial experience has taught me, avoiding altogether the literature of the theatre, as well as those strictly architectural portions of design or construction with which doubtless every member is conversant. The most convenient plan will be to take our subject under various heads, of which the following are perhaps the most important:—

General Arrangement:—Entrances and Exits for Audience.—Heights of Tiers for Boxes.—Line of Light.—Construction of Stage.—Mechanical Arrangements of Scenery.—Painting Room and Scene Docks.—Accommodation for Managers and Artists.—Workshops for different Departments, viz. Property Maker, Carpenter, Gasman and Metal-worker.—Lighting of Auditorium and Stage.—Lime Light.—Water Supply.—Heating, Ventilation and Decoration.

First, then, as to general arrangement. In forming the first idea I tried to avoid what I consider to be a defect in most of our best theatres; even Drury Lane, with all its magnificence, has this defect specially marked, a certain coldness and want of comfort in the entrances, staircases, and passages. I therefore tried to assimilate my plan to that of an ordinary mansion with its entrance-hall, staircase, ante-room, and grand saloon, so that once having passed the entrance we should be in a suite of rooms instead of again entering cold passages and corridors. By looking at my plans you will perceive how I have attempted to carry out this idea. Firstly is a carriage-drive, leading into the crush-room, of ample size, to the right; the audience is conducted by the grand staircase, 10 ft. 6 in. wide, into the *foyer* or ante-room, through which all *must* pass, thereby avoiding a cold useless room, merely attached to the theatre, and from thence at once to the "salle," the French term, which I shall use in preference to "auditorium." The corridor is here merged into what are usually termed the boxes. I adopted this plan first at the Prince's Theatre, Manchester; the advantages are many, *e.g.* a greater freedom of circulation, a space obtained for standing room on crowded nights, and a more elegant appearance. I am not sure that this plan would answer in the Metropolis, as there is not that privacy in entering the private boxes, which I think a London manager would consider most desirable.

You will perceive that the theatre proper is on the first floor, by which plan a large amount of valuable space is gained, a most important point, considering the present value of land; it prevents draughts; the gain also is great in the stage, which I shall enter more fully into when treating of that

portion of the theatre. The only disadvantage is the necessary extra number of steps to the various parts of the house. The first point of consideration in commencing to work out the plans was the width of the opening of the proscenium. The advantages in making it larger (it is only 29 ft.) would have been a greater capacity in the *salle*, as naturally the circles would be larger, and a grander effect would have been obtained; but I think this is far more than balanced by the disadvantages in this, a provincial theatre. A large theatre when not filled looks very cold, and naturally has a chilling effect upon the audience, and as there are often many "poor nights" in a year (and, unfortunately, sometimes more than good ones), this should be taken into consideration. Again, to secure an adequate effect upon the stage, a wide proscenium requires a proportionate number of performers; for instance, where Drury Lane would require at least a ballet of 24, one of 16, or even 12 suffices in the Alexandra Theatre, and probably by the general public the difference of numbers would not be appreciated; and so throughout with supers, &c. This, of course, applies also to scenery, &c., which requires to be so much less in size, and effects a saving not only in material, but also in the labour of working; the largest cloths in a theatre in England, are at Covent Garden, where they are 70 ft. by 50 ft., while at the Alexandra they are 40 ft. by 28 ft.; and although not double the size, I am sure they cost at the former twice as much, with working, as at the latter. The opening of Covent Garden proscenium is 50 feet. It is also very desirable to have a small stage for comedies, farces, and other light pieces, where the audience should be able to see distinctly the facial play and finer points of acting, which would be lost on a large stage. For example, I am sure, if the Prince of Wales' company, admirable as it is, were transported to Covent Garden, the great perfection of the acting would be lost.

The proscenium opening of the Prince's Theatre, Manchester, is 26 ft., and this I thought too small for the purpose which the directors had in view. Having settled this point, the next was the consideration of the plan of the fronts of the circle. In my opinion the most perfect form would be a semi-elipse, with its long axis parallel to the curtain line. This, however, practically would not do, as the number which such a formed theatre would hold would be too few; therefore a modification must be made, and, taking all circumstances into consideration, convenience, number of audience and beauty, the horse-shoe plan, and its various modifications, is in my opinion undoubtedly the best, although I have recently built a theatre of a novel form, and which, when treating of the line of sight, I shall more particularly refer to. In this case, being rather pinched for space from back to front, I may say that the curve formed itself, as I had to a great extent to be ruled by the formation of the ground, and it was desirable to get as many rows of seats as possible. One peculiarity is, that the pit does not extend under the boxes. This, after mature consideration, was decided upon by the directors, who, I may here remark, were some of the leading gentlemen of Liverpool, whose object in building the theatre was not gain, but to have a handsome and luxurious house, worthy of the town. The pit being the best part of the theatre, they said they would devote that part of the house to those who paid the most, and therefore the pitites were promoted to the tier above the dress circle. This did not naturally meet with their approbation; and it was afterwards found desirable to devote a portion of the stall space to them, and the theatre is now so, although at opera times, and other special occasions, the original arrangement is adhered to. I need not here enter into a dissertation on acoustics, a science with which doubtless all here are well acquainted. I can only say that the natural form of a theatre is the best adapted for sound, and to make success certain, it is only necessary to use wood in the ceilings and wall linings.

Entrances and Exits.—The paramount importance of providing ample entrances and exits, with easy staircases (without winders) in all public buildings, is no doubt duly estimated by you; still I should like to make a remark or two on this head in connection with the theatre. In all cases, I think, the place of exit and for entrance should be the same, because as soon as ever an alarm takes place the

audience naturally rushes to the doors by which it entered. These should be of ample size. The staircases of the Alexandra are not, I regret to say, all I should desire, although perhaps larger in proportion to the number of the audience than any theatre in England. It is, however, more in arrangement than size that they are defective, and to this I was compelled by want of space. You will perceive that the pit, circle, and gallery stairs are in the same staircase, 6 ft. 6 in. wide. There are good landings, but there are also some winders with which I would gladly have dispensed, but they were a necessity in consequence of the above-named arrangement. I do not think in any case there should be a flight of more than from 8 to 10 steps without a landing. I find the following a good rule for the width of staircases; for any number up to 100 the staircase should be not less than 4 ft., with an additional foot for every 100 persons. Thus, suppose a gallery to hold 700 people, the stairs should be 10 feet wide; in the Alexandra, I consider the gallery stairs about 2 ft. 6 in. too narrow, as it holds the above-named number.

No one can be insensible to the importance of providing properly for the escape of an audience, whether from actual danger or from panic; and the more so as it never seems to have been satisfactorily settled how to prevent, or at least mitigate, the headlong rush and trampling which have so often occurred on these occasions. No doubt a wide passage is much better than a narrow one, where a large crowd of persons are all moving rapidly along together. But then the larger the aperture the more danger there is of the stream being overtaken and forced into a heap of fallen bodies by the pressure from behind, which, having no means of resisting the force, can only succumb to it, as in the fearful tragedy at Santiago. To prevent this I propose to divide the passage into parallel sections by barriers 2 ft. 6 in. apart, and about 3 ft. 6 in. high, which would allow two persons to pass abreast; so that every one could, all the time they were moving, have a support to lay hold of, and would only have to sustain the weight of the one or two immediately behind. For the same reason, but in a greater degree, the staircases should be divided in the same way.

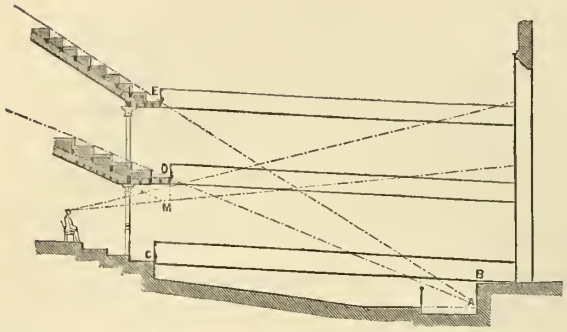
In planning the front of the house care will be required in the position of the money takers and checkers, so that they may have proper access from the treasury behind, and be under the immediate control and inspection of the manager while the audience is coming in, so that any purloining or other irregularities may not be easily carried on. The manager's room should be within easy access of the stage and the offices and rooms in connection with it, but its situation should be private, for there is no man whose privacy is less regarded, and he should therefore be out of the immediate reach of casual visitors and idlers. In the Alexandra it is placed just between the green room and front of the house, so that, should occasion require his attendance at either end, he would be close at hand.

In consequence of the dress circle being nearly on the level of the stalls, and there being only two tiers above, I had less difficulty than usual with the height between the tiers. It is of course desirable that there should be as much head room as possible between each tier, not only for the sake of appearance and comfort, but also for ventilation. It must, however, be borne in mind, that the higher they are the greater the number of steps required, and as the back of each tier is necessarily the highest part, owing to the slope that is required to give the proper line of sight, this height is still further increased; so that in arranging the several tiers due regard must be paid to these essentials, as well to the class of house intended and its requirements.

The line of sight is the next most important point that claims our attention. The simple rule I have adopted can be best explained by reference to the diagram; of course the object to be attained is a full view of the actor on any part of the stage, and if he can only be seen when near the float or footlights he naturally can be seen when on any other part of the stage.

If a line be drawn from the points C, D and E, (that is, the front steps of each tier) to the point A, where the floor of the pit meets the stage, we shall have a line in each case which the points of the steps must touch. Now as the eye of an average man is 4 ft. 2 in., when sitting, from the floor, it necessarily follows that the spectator can just see the point B, (which should be about 4 feet from A), and therefore the foot of the actor, and consequently the whole person, but as we get towards the sides of the theatre the line gets shortened, and hence the great difficulty of seeing, which we so often experience in theatres. But if we adopt the same rule and form another section and draw a line from each point as before from G, H and I to F, the centre of the stage, we shall find the risers increased very much, so that where perhaps a riser in the second tier may be in the centre of the house perhaps 12 inches, at the side it would probably be 2 feet. Even this would not enable the spectator to see the actor if on that side of the stage nearest to him; but as it is impossible for any but the first row to see any one immediately under him, the best must be made of the circumstances, and I consider it in practice sufficient if an object can be seen at two-thirds of the stage; thus the line should be drawn to a point K instead of F; and here is the advantage of having private boxes, for the public is satisfied in a box if two only can see properly, whereas every one expects, and ought to have, a full view in open seats. To assist the line of sight I have in this, as well as in other theatres I have built, instead of letting the tiers run horizontal, sunk them towards the proscenium, in the case of the Alexandra, to the extent of 1 ft. 9 in., thereby the spectator being nearer the stage the line of sight will not form such an acute angle; there is also the advantage of giving those sitting at the sides, and consequently who have to see over a greater number of heads, a better opportunity of seeing.

No. 1.



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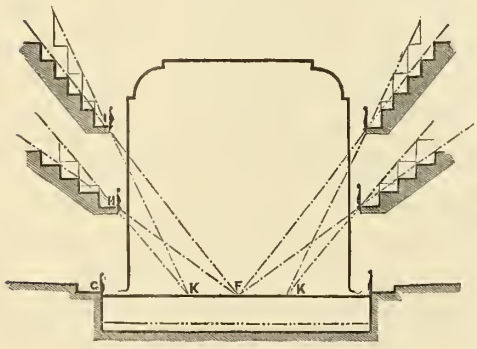
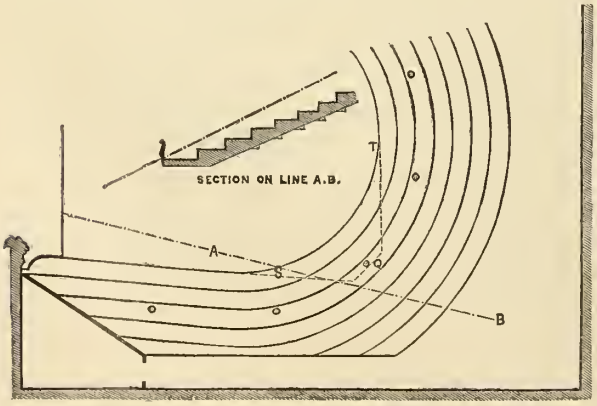


To assist the spectator to see as much above the stage as possible I have adopted the plan shewn in this drawing, instead of bringing the raking beam down to the front, there is a casting, as shewn, from the column; thus the spectator would see much more of the stage than if the beam came down to the point M (see diagram No. 1); another advantage is, that the front of the boxes need only be about 3 feet deep, which gives great lightness to the appearance of the house.

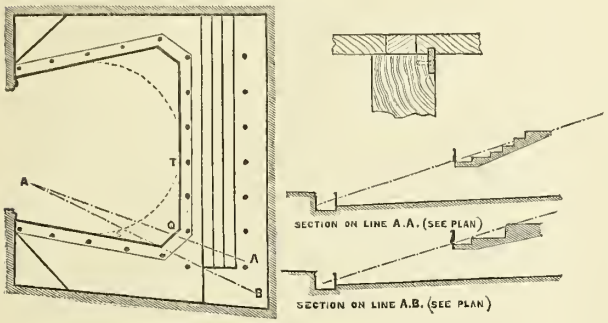
No. 3.



If we refer to diagram 3, the great difficulty is seen of getting a proper line of sight, when there are a number of rows of

seats, six or seven, or even eight and nine, as is sometimes necessary, to get accommodation for the requisite number of people. Finding that the part contained between the points S, T, Q was always so much in the way, it suggested itself that a form without these spandrils, that is, a rectangular form, would give better sight; I therefore, in a second-class theatre, which I erected in Manchester a few months ago, adopted this shape. This is the plan. And the result, as far as a large number of the audience having a first-rate view of the stage, is most satisfactory; but the form is anything but elegant, and the appearance is cold and cheerless. I might say, that want of time (the theatre was built in six weeks) and limited funds were other reasons that induced me to adopt this form.

No. 4.



The all-important subject of construction of the stage, in which I include all those parts that are necessary for the working of the scenery, &c., stands next in our list, to enter thoroughly into this subject would take me beyond my prescribed limits. I will try, however, to point out the most important features and points that are necessary to be observed. I may say I do not approve of the English mode of working scenery; I object most strongly to the general use of flats, and consider that the continental theatres are far in advance of ours in this department. Here, unfortunately, we have to contend with the ignorance of stage carpenters and managers, and their prejudices in favour of old stereotyped forms and antiquated mechanisms are so rooted that it is almost useless to attempt any change, as it is sure to end in their making all the obstacles they can where difficulties appear, and creating them where they do not exist. I have been told often by managers that I am not *practical*, my theory was very nice, that they agreed with me that the grooves were most unsightly things, but they knew that the theatre could not be worked without them, and when I have answered by telling them that in the continental theatres such things as grooves are not known, my only response was perhaps a shrug of the shoulders. I think, then, that all scenes that are not practicable should be painted on a cloth. The word cloth in stage parlance signifies any scene touching the stage, not strained in frame work, and worked either by roller or pulled straight up with battens top and bottom. What can be worse than the way in which we see a landscape scene constantly put on the stage, at Drury Lane for instance. First the two flats are pushed forward in the vain hope that the upright joint (very often a bad one, and plentifully bedaubed with the dirty finger-marks of the scene shifters) will meet without being seen, then a border has to be lowered to make up the necessary height and mask the grooves and border lights, then the side scenes or wings have to be pushed on to make out the requisite width. Here we have four joints all perfectly visible, whereas, if a cloth had been used we should have had none, for the size of the cloth would be just equal to the five pieces, named above, put together; there is, besides, a great saving in expense of wood framing, less time is taken in painting, and one man does the work of five. I am supported in this view by Beverley, Grieve, Telbin, and all our great scene painters, who constantly regret the difficulties they have to contend with. Covent Garden is the only theatre I know in England with the stage constructed on this principle, and the finest scenic effects are got there. The height from the stage to the gridiron floor should be double the height of the cloth; and the Prince's Theatre in Manchester, the first theatre I built, was the first one in England in which this could be done. Now the size of these cloths must be decided by the architect, so that the

flies, gridiron floor, should have their proper relative position, and the painting frame be of the proper size. The opening of the Alexandra proscenium being 29 feet, the cloths should be 14 feet wider, or better, 16, that is, 43 to 45 wide, but for want of width I could only get them 42, and the height is 27 feet. The flies are, therefore, 43 feet apart, and the height from stage to gridiron floor 54 feet, thus allowing the cloth to be taken straight up out of sight without folding, a great economy is thus gained in the working and space.

It is a great defect at Covent Garden, where the cloths are 50 ft. high, that they have to be taken up in three folds, an arrangement which must of course require a multiplicity of ropes and battens, an increase in the wear and tear of the scene, besides taking up three times the space, a point of great importance. When the Alexandra was opened, there were no grooves either for flats or wings, the wings being worked on movable ladders as at Covent Garden, and the necessary framed pieces and flats for interiors and other practicable pieces were worked in a panoramic groove, that is, a framed piece out of sight, which could be let down in grooves for these framed pieces to slide in; but, I believe, about a year since they altered this arrangement and went back to the old system. They still, however, have as many scenes as possible on cloths, which is in itself a great gain. The height of these wings and flats I fixed at 19 ft.; the depth under the stage should be sufficient to allow these pieces to sink out of sight. The width of each flat is 14 ft., and sufficient space should be allowed on each side to draw these off with an ample passage beyond. It economizes the working of the stage; the men do not get in each others' way; there is more room to remove and place properties, and therefore less chance of their being broken and damaged; and the dresses of the actors, and more particularly those of the actresses, are not so liable to be spoiled. In this respect the Alexandra is deficient, although better off than most theatres. Beyond this, again, on each side there should be some docks of sufficient depth to take a flat: for the reason above stated this could not be done. Drury Lane is very well planned in this respect.

The floor of the stage should rake from back to front, for the purpose of assisting the perspective effects, and giving greater ease to the performers in various actions, particularly in dancing —1 in 26 I find to be the most satisfactory gradient. This inclination causes a natural tendency in the whole of the stage to bear forward, a tendency increased owing to the absence of any longitudinal ties, which, as the bridges and sinks have to work transversely, must be dispensed with. To prevent this bearing forward, the stage joists are usually locked (as it is termed) with iron hooks from joist to joist the whole length of the stage, and before any bridge or cut can be used those fastenings between the joists of such bridge or cut must be undone, and a most unsatisfactory mode of working it is in this mechanical age. On reference to the section taken through the stage, you will notice uprights at various distances to support the joists. At the Alexandra I placed these uprights two inches out of the perpendicular, so that before any strain could push them forward, it must first push them *up*, a tendency which would be resisted by the flooring. This plan aswered well for a year or so, and I learnt only a few months ago that they were obliged to lock the joists in the old fashion, the necessity being caused, I fancy, by the gradual giving and loosening of the joints, and most probably shrinking of the timber. I have here a section (showing a plan) which I anticipate will answer, but have not yet had an opportunity of testing. Instead of the sliders working in the usual way, I should fix an iron fillet on the edges working in a groove, thus each slider forms its own lock between its joists. I should very much like to have the opportunity of erecting a wrought iron stage. I feel convinced that more rigidity, and consequently more perfect working, could be secured in iron than any other material; but I am afraid it would be difficult to find a manager willing to go to the requisite expense. The mezzanine floor should be only about 6 feet 6 inches under the stage, so that should any lever, rope, or slider go wrong,

the men below could at once reach the defective part without the trouble or time necessary to fetch a ladder. I do not intend to enter into the mechanical details of the working of a stage. I could well write a paper as long as this, on this subject alone. This department is, perhaps, more that of the stage carpenters than the architects. My interest in my subject has, however, caused me to make a speciality of this department, and I have endeavoured to make various improvements in it, and I trust with success.

The painting room is placed on one side of the stage. It would have been much more convenient if placed at the end; but I had not sufficient depth to do so. The size, of course, is ruled by the size of the cloth. Especial care should be taken that the frame is high enough to have the canvas stretched in one. It is very frequent, in fact very general, in most painting rooms, that when painting a cloth, it has to be done in twice, a defect which increases the working expenses, since not only have the carpenters to move the cloth after it has been once stretched, but the artist also must work at his picture in patches, and stop at a certain line, however much it may interfere with his painting. In architectural subjects this is particularly annoying, as I myself have experienced. I recollect some years ago painting a scene: it was a town scene, with a tower rising high into the picture. The first twelve feet were stretched only (this being the depth that the frame was short in height), and consequently I had to guess the position of the vanishing point, as I could get none until I got to the lower portion of the picture.

If I were to consult any artiste, particularly an opera singer, about the requirements of a new theatre, the first thing that would be earnestly impressed upon me would be the necessity of having the dressing rooms very comfortable and very conveniently disposed. There must be no draught, the rooms must be within easy access of the stage, the steps conducting to them must be as few as possible, and they must be away from the stairs that lead to the dressing rooms of the chorus, ballet or supers. Very necessary it is to give these matters full consideration. In the Alexandra the space would not allow me to arrange these rooms as I should have wished. I was able to get only one dressing room on the stage level: this, of course, the prima donna or "star" would have, and I was taken to task by one of the Italian Opera troupe for not providing a second one, a certain lady thinking she was quite as much entitled to this room as another certain lady. It is, however, very desirable that at least four such rooms, two for ladies and two for gentlemen, should be provided. The stairs leading to the ballet and chorus room should, if possible, be at the end of the stage, so that there may be as little noise as possible. A sense of propriety will also suggest that the dressing rooms for males and females should be approached by different staircases.

Two green rooms should be provided, one for the principals and one for the ballet, &c., as the *upper ten* are very aristocratic in their notions, and do not like mixing with the *middle orders*. I have constantly seen the green room, when there is only one, deserted by the principals on this account. They prefer to retire to their own dressing rooms during the intervals when they are not required on the stage. In this respect the Alexandra is deficient.

The musical portion of a performance having now attained such a degree of excellence in every well-appointed theatre, it is necessary that the orchestra should be of sufficient capacity to accommodate the full complement of musicians for a powerful and well-balanced band. In connection with the orchestra there should be a room for the assembling of the musicians and for tuning, so placed that the sound of the instruments should not be within hearing of the audience, and another room for practising. There should also be a library for musical literature and score, which, it is indispensable, should be fireproof. For want of this provision the disastrous fires at Covent Garden and Her Majesty's destroyed priceless musical treasures. The orchestra itself is about nine inches below the level of the stalls, so as

not to interfere with the view of those sitting in the front rows. It should be constructed like a huge box, giving thereby a greater fulness of sound. We all know how much louder the sound of a musical box is when placed upon a box than on some solid non-vibrating substance.

The different workshops are important appendages to the theatre. The carpenters' shop in the Alexandra is placed below the stage on the mezzanine floor. It was here I had the most room, with a good light. If it could have been placed on a level with the stage it would have been more convenient, as there is some difficulty in its present position in getting out the large pieces of frame-work that are so constantly being used in a theatre.

The property department is perhaps as important as any, and requires more room than any other both for storage and making. I may explain that the term properties imply everything movable on a stage, not scenery, from an elephant to an inkstand. These accumulate very fast. Some of them are very costly, so that there should be sufficient room to store them carefully away. There should also be a small room near to the prompter, so that the properties required for the night's performance may be close at hand. There is a want in the Alexandra of a good sized room, for the stowing away of furniture. In the rapid change of scenes there is necessarily an amount of rough treatment, and as we have now sometimes on the stage rooms furnished as elegantly as in a private house, special attention should be paid to this. A well-lighted room of ample dimensions is also necessary for the making of properties. The position of this is not of great importance, care being taken to have an ample passage from it to the stage, to allow for the moving of the bulky articles, such as the elephant before alluded to. You will see that I have placed this room behind the gallery, where there happened to be the greatest space: it is well lighted from above.

The gas arrangements for the stage are very important, the ordinary method adopted is perhaps the best, by means of borders, wing lights, and float or foot lights; the latter in the Alexandra is somewhat novel, which I devised, and Messrs. Defries carried out and patented. There is a channel behind the burners leading into a flue built in the wall, which draws off the vitiated and heated air; in front are two frames filled in with coloured glasses, worked by a lever from the prompter's box, as the effects may be required. The top of the burner is on a level with the stage, and the top of the iron box five inches above, so that the view is very slightly impeded, and from no part of the house can the flicker of the flame be seen. I have here a drawing of the arrangement to work the various gas lights over the whole house, and which must be under the immediate control of the gasman. You will perceive that each particular border or wing light can be lowered or raised at pleasure, or the front two of either can be governed by one tap, or the whole of either can be regulated also by one tap, or the whole together are again under the command of one tap.

Besides the gas lighting, it is now very important that the architect should make provision for the lime light. In the Alexandra the gas meters are placed in the cellar below the stage, perhaps as convenient a place as could be found. Supply pipes for the two gases are laid in the usual way, each lantern having india rubber tubes to attach to the supply pipes. A work room should be supplied for the gasman; it is here on the cellar floor level, with a forge, the latter being very necessary, as the gasman has to execute all kinds of metal work, and a clever gasman will be able to make armour and arms. It would be very desirable to light all the gas by electricity: a saving of gas would be effected, and a great source of danger from fire averted. I hope to see this done before long. There is no practical difficulty in it that I can see.

The very important questions of ventilation and heating will next occupy our attention. The Alexandra is heated by hot air. I adopted this in preference to hot-water pipes, as it is more rapid in its effect and the currents more easily regulated. It is only necessary to heat a theatre for a short time

before the audience assemble, the people and gas keep it warm enough afterwards, and it is therefore of vital importance to get rid of the products of the gas and vitiated air. The usual way of abstracting the vitiated air in a theatre is by a large ventilating shaft over the chandelier or sun-burner. The heat of the gas in the sun-light causes a strong current, and no doubt effectually draws away a great amount of foul air. But after the audience has assembled some time, the moment the curtain is raised a great rush of comparatively cool and fresh air finds its way from the stage, and naturally flows towards the centre light, and is at once carried off, and thus to a great extent wasted. Some penetrates under the boxes, and causes eddies and currents; but these are currents of foul air, as there is no regular current from the differerent circles, where the audience really are, for the above-named reason. I therefore nearly closed the shaft above the sunlight, so that the fresh air from the stage, and the channels provided for the admission of fresh air, flowed at once to the different circles, at the back of which I provided outlets into flues which above the ceiling went into the great shaft above the sunlight, and thus utilized the heating power generated. By adopting this course, I simply took advantage of the natural current of air, for instead of the stream of air flowing towards the sunlight (as there is practically no outlet in that direction) it must flow towards those which are provided at the back of the tiers: thus all conflicting currents are avoided, and the ventilation is sustained and maintained in one direction. I may here remark that the result has been very satisfactory.

Great care should be taken to allow for an ample supply of water, and a proper system of stand pipes in case of fire. The ordinary system adopted is as perfect as any I know. As many turncocks as possible should be provided with hose ready attached. In a theatre it is not difficult to extinguish a fire if taken in time. There are more *narrow* escapes in theatres than the public are usually aware of. A prevalent idea exists that scenery is very inflammable; such is not the case. The paint used—distemper—is not easily combustible. I have tested a piece of canvass covered with paint, and it is very difficult to burn, impossible to set in a flame, it will smoulder. What makes a theatre so liable to fire is the quantity of wood, not only on the stage, but throughout the house; that on the stage could scarcely be better disposed for catching fire, with its light scantlings and air spaces between. As water is now abundantly used in scenic effects, it is well to provide a large cistern for an ample immediate supply, and to lay, as I have done at the Alexandra, a drain, with an eye in the centre of the stage to carry away the waste water.

I have alluded to the difficult question of acoustics; fortunately the general form of a theatre is most favourable to the conveying of sound. It is said that there should be as little raised decoration as possible, so as to allow a free surface for the passage of sound, and to this the perfection of the acoustic properties of the late Her Majesty's Theatre was in a great measure attributed. I am doubtful whether this was the cause, as the whole of the boxes, and the theatre was almost all boxes, were hung with curtains, the worst conductor of sound and quite sufficient to counteract the good effects of the level surfaces of painted ornament, which, by the way, were painted on canvass, a non-conducting medium. I attribute its perfection to its form, and the boxes and fronts being made of wood; and this accounts for the great rapidity with which it was gutted by the fire.

I am strongly in favour of raised decorations. In my opinion no similarly rich effect can be attained by any painting, however good. And if the painting be not of a very first-class style, which is most difficult to obtain, and if obtained very expensive, it has a tawdry effect, and resembles ordinary paper hanging ornament. I have here the small drawings of the enrichments of the Alexandra Theatre. The panels in the box fronts are filled in with blue tufted satin, which gives a very rich effect, and is not expensive. I was at first a little afraid that this would interfere with the sound. But I argued that

if the mass of loose drapery at Her Majesty's late Theatre had not that effect, the satin panels would not either, and the result proved that I was correct.

I cannot here resist the temptation of giving you an extract from the *Times* of October 22nd, 1867. It appears that Mr. Oxenford, the *Times*' theatrical critic, had paid a visit to the American theatres, and written various notices on them. The following extract was written on his return, and is dated from Liverpool: "Having now completed my tour of the New York theatres, the most fitting conclusion to my short series of letters will, I think, be an enumeration of the results I deduce from my observations and enquiries. I give this in the form of a report, incurring the risk of being charged with self-repetition, or even of self-correction, if this letter be compared with those that have preceded it. 1. With the exception of the Bowry, the New York theatres, considered as edifices, furnish models which the London architect would do well to imitate, as they are light, commodious, and so arranged as to allow nearly the whole of the audience a good view of the stage. The theatres in London that mostly resemble them are Astley's, in its present condition, and the small house at Highbury Barn. But a far better imitation, one indeed that exceeds the originals, is the Alexandra Theatre, Liverpool, in which the lightness of the American house is qualified by gorgeous 'appointments' scarcely to be matched anywhere."

I may here remark that I have never been to America, nor have I ever seen any drawing of an American theatre.

Though it scarcely comes within the scope and purpose of a paper such as I have had the honour to read to the Institute to-night, to allude to the present condition of the drama in England, yet I hope I may be excused for venturing to assert that it is not now in that condition which we would wish to see it. Shakspeare is seldom played in any of the metropolitan theatres, and the real legitimate drama has retired to make room for the attractive burlesque and extravaganza. Managers tell us that neither tragedy or comedy will *pay*, and that they must follow the public taste, and not their own inclination. In England, as you are aware, our governmental policy is not like that of other countries, to give subsidies to theatres, and we religiously pin our faith on the exercise of public and private enterprise for supplying us with theatrical amusements, and that free trade in the production of the drama is the soundest policy. I, however, confess, in this case, to Protectionist notions, for I am convinced that with the abolition of the patent theatres of Covent Garden and Drury Lane came decadence in the Shakspearean drama. Some few years ago Mr. Phelps and Mr. Charles Kean, by their personal exertions and labours, did much to revive the taste of the glorious works of Shakspeare at Sadler's Wells and the Princess's respectively; but now-a-days we have no chance of seeing one of his plays unless we go to the provinces, as, for instance, at the Prince's Theatre, Manchester, where his *Timon of Athens* is as well performed as it is possible to be. Is this state of things to last? Some will say, Yes! until some great 'Hamlet' or some wonderful 'Lady Macbeth' shall spring up. *My* answer is, No! it should not last, for my belief is, that if the public of England be asked to erect a national theatre at a cost of some £ 50,000., the money will be found. Are there not five hundred men of wealth in this country who, without the slightest desire of profit to themselves, will subscribe this sum, provided they could be assured that the theatre would, by a well-tried special trust, be devoted to the production of the works of our immortal bard, and to such other works as could come within the true definition of the legitimate drama? I have heard this project propounded, and I believe in its ultimate realization, if it be only carried out with honesty and singleness of purpose. Then, Sir, we shall find the young actors and actresses in the provinces struggle in their ambition to get to the national theatre, and a school will ere long be established, which will make its mark on the taste and character of the present time and on future ages.

Mr. O. Hansard, Fellow.—I wish that some one more able than myself had risen to propose our very best thanks to the author of the paper with which we have been favoured to-night. I regret that Mr. Salomons has not enlarged more upon the general construction of his theatre at Liverpool, and (from the great experience that he seems to have had) on that of others. I mean by construction, that of leading us over the greater difficulties, such for instance, as that of carrying the auditory upon the several tiers, so as to give all a good view of the stage. I think, myself, if we could have had rather more lucid explanations of the drawings as our friend read his paper, we should have followed his ideas better, and I would take this opportunity of suggesting that, on future occasions, when gentlemen from the provinces favour us with papers, and are not able to bring an assistant with them, arrangements should be made for some one to point to the drawings and sections as they are referred to. I hope some of these drawings will be lithographed, and will accompany the printed paper in the transactions. With respect to two of the sections—I may be wrong in my views—but I do not comprehend from the rapidity with which the illustrations were referred to, how our friend gets over the different levels on each tier formed by the increased height of seats at the requisite angle, so as to see his stage. I recall to remembrance two very beautiful little theatres, one the elegant opera house at Venice (la Fenice), the other at Brescia, which are, if I remember, formed partly on an elliptical and partly on the horse-shoe plan. The one at Brescia is nearly of the horse-shoe form, with an elliptical ceiling, and is (or was twenty years ago) an excellent specimen of cinque-cento decoration. Both these theatres are very perfect in their plan; but I do not recollect the difference of the jump or rise, as we may term it, as shown by the sections of the one at Liverpool. In the Haymarket Theatre, although it may be faulty in respect to coldness and lack of decoration, I would say, with the exception of two or three back side seats in the dress-circle and the upper boxes, there is no theatre in London in which the audience have a better view of the stage, and none in which the accommodation in the pit is so good. If some modification in form could be drawn, by which we could combine the luxurious arrangements of the Gaiety with the admirable viewing plan of the Haymarket, I believe we should have a theatre of a form which would gratify the public, and be of great benefit to the management. There is another point I would call attention to. Our friend has referred to the acoustic property of the late Her Majesty's Theatre, and alluded, as I understood, to the curtains, &c., of the boxes being partly the cause. I perfectly remember the materials of which that roof was constructed; and I believe the excellent acoustic principles, independent of form, though no doubt form had a great deal to do with it, were mainly due to the fact that the whole of the interior roof was lined with wood. With these few rambling remarks, I conclude by proposing a vote of thanks to our friend for his excellent paper.

Mr. Horace Jones, Fellow.—I shall be happy to second that proposition, and will offer one or two remarks that occur to me. I believe that the roof of the late Her Majesty's Theatre was composed of yellow pine; and there is at present in Paris, if it is still left untouched by the raids of the Germans, or by the still greater raids of the inhabitants of La Villette, the Conservatoire de Musique, which, I believe, was erected about the middle of the last century, the small theatre attached to which was re-built some thirty or forty years ago, when the whole of the orchestral portion was carefully preserved, and re-erected in the new building, it being composed of *bois de sapin*, which was brought from a considerable distance. I have heard it expressed to me as the sound being as soft and sonorous as that of an old cremona; and that bears somewhat upon the question of material in regard to the acoustic properties of theatres. There is a gentleman present (Mr. Anderson) who, I believe, can give us some valuable ideas with regard to the construction of theatres, and it would be very agreeable to us, I am sure, to hear the views of gentlemen, as it were, on the other side of the question.

Mr. Anderson.—I am quite unprepared to make any remarks; but I have listened with a very great deal of pleasure and satisfaction to the paper.

Mr. W. S. GILBERT (on the invitation of the Chairman) said:—I am here altogether ignorant of the subject under discussion, and indeed I come here as a novice to be instructed myself. I have been very much delighted with the paper; but it would be wholly beyond my province to offer any remarks upon the subject.

Mr. C. J. PHIPPS, Fellow.—With regard to the arrangement of the Haymarket Theatre, I agree with Mr. Hansard, that it is unadvisable to carry the pit under the boxes. The dress circle, and other parts of the house, are thus raised so high above the stage, that dissatisfaction is caused to the audience there, and to the occupants of the pit underneath the boxes. I have erected one theatre, at Bath, where the pit extends only to the enclosing line of the boxes, which I consider the correct principle, constructionally and architecturally. It is, however, entirely a managerial matter; managers set themselves against that plan, from a pecuniary point of view, and architects may protest, but have to submit.

Mr. R. P. SPIERS, Associate, said:—With regard to the question raised as to the construction of Her Majesty's Theatre, a paper was read here some time ago by Mr. Warrington Taylor, and if I remember aright, the acoustic properties of that house were ascribed to the ceiling having been formed of hollow rods covered with plaster. When the new theatre was being erected, the architect, Mr. Lee, showed me the drawings of the old building, and pointed out that, at various epochs, the thickness of the walls throughout had been increased by battening out, so that the acoustic properties were possibly due, in a great measure, to the peculiar formation of the theatre ceiling, and the series of hollow spaces behind the several wooden partitions. There is one point which Mr. Salomons has omitted to notice, which it may be well to allude to, that is the difference between the objects held in view in a French and an English theatre. It is well known that theatres are more popular in Paris than in this country, and that they are the most general places of resort, not only of the higher, but also of the lower classes; and it would seem that the French people have had objects in going to them, one is to see the performance, and the other, no less important, to see and be seen by their friends during the somewhat long *entr'actes*. The crush room in those theatres is a necessary feature, and the theatres are so arranged as that, from almost every part of the house it is possible to see everyone in it. I remember that at the time of the competition for the new Opera House in Paris, there were some 150 designs sent in, and the persons who had the selecting of them at once struck out of consideration those designs which were not based upon the principle I have referred to. The authorities determined from the first that the arrangement of the auditorium should be similar to that which existed in the old Imperial Opera House, and several designs which pointed out better arrangements in other respects than those which were adopted were rejected. Several of these rejected designs were arranged upon the same principle as the old Greek and Roman theatres, that is, semi-circular in plan, the seats being raised one behind the other. The difficulty which occurs in that form of theatre lies in the construction of the ceiling, which must necessarily be of immense span; but there can be no doubt but that it would answer better the requirements of the English public, who scarcely desire to see so much of one another as to have a good view of the stage and performers.

The CHAIRMAN.—I may refer to the fact that in one of the theatres in Paris there is a glass roof, and the lighting is from above the roof, which I apprehend is done to prevent the great heat which the chandelier universally used in England sends into the body of the house. I should be glad to hear the opinions of gentlemen upon the advantages or disadvantages of that mode of lighting.

Mr. SALOMONS.—Before I built this theatre, I went to Paris to see if I could find any novelties worthy of my adoption of the kind that have been introduced into the Gaiety. The manager, whom I knew, showed me the whole of its details. With respect to the lighting through the ceiling just referred to, I found that the consumption of gas was enormous, being six or seven times what was

required for lighting under other arrangements. I confess I thought the effect was unpleasant, and to my mind there was not sufficient light. It was not at all brilliant, and the absence of heat in the theatre seemed to me the only apparent gain. The advantage I considered slight, while the expense was so great, that I at once gave it up.

In reply to a question from Mr. Hansard respecting the arrangement of seats in the auditorium of the Alexandra Theatre, Mr. Salomons said, the box fronts are not level at any part: they slope towards the stage. The point I aimed at was to have no steps at all; consequently the passages are in no case level. There is no inconvenience in this. In some places the rake is as rapid as one in twelve or fourteen. This is preferable to having steps. The object in a provincial theatre is to get as large a number of rows of seats as possible in the boxes, whereas in an opera house they have only two rows of seats to the boxes. The difficulty arises where you have a number of rows, in order to accommodate the necessary number of people, and this is particularly the case with respect to the gallery. In the new Surrey Theatre those at the back of the gallery could not see at all, and it had to be taken down and done again. Errors of the same kind have been made in other theatres which have been built within the last eight or ten years.

Mr. C. J. PHIPPS explained a method he had adopted of preventing the forward motion of the stage.

Mr. SALOMONS, in reply to an enquiry from Mr. Blashill, stated that in the case of the Alexandra Theatre, as also the Prince's at Manchester, the inclination from the front of the boxes to the stage was one foot nine inches. The greatest inclination he was acquainted with was that of the new Theatre at St. Petersburgh, where the fall was equal to the depth of the box fronts.

The CHAIRMAN, in the name of the members present, conveyed to Mr. Salomons an unanimous vote of thanks for his paper. The meeting then adjourned.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 17th April, 1871,
THOMAS H. WYATT, President, in the Chair.

THE preliminary business of the evening having been concluded,

THE PRESIDENT rose and said,—Gentlemen, having got through the routine business of the evening, I proceed now to the more agreeable duty of presenting the Medals and Prizes which have been awarded for the present year. I begin with the Royal Gold Medal [addressing Mr. Fergusson, the President continued],—Mr. Fergusson, It would have been more gratifying to me if the duty of presenting to you this Gold Medal had fallen to other hands; such, for instance, as my predecessor in this chair, who would have stated with far more power and ability than I can do the various and numerous claims which you have to the honour that has been conferred upon you. For my own sake, however, personally I rejoice that the duty of handing to you this medal devolves upon me, because it affords me an opportunity of stating before this assembly how long, and with what personal regard and esteem I have viewed your character and professional career—feelings which have been increased by the intimacy of later years.

It is not, I believe, generally known how this medal has been appropriated by the Institute. Though no definite rule is laid down, the custom hitherto has been to award it—first to a foreign architect or archæologist, or antiquarian of distinction; secondly, to an English architect, who has executed or designed a work of great merit; and thirdly, to one who has contributed works on the history of the profession, or on subjects connected with architecture: or on one who, as Mr. Beresford Hope happily expressed it, "has unfolded the secrets of old times, and led us back to the thinkings of other days." Happily for you, sir, it may be, you have not had occasion to follow the arduous and anxious practice of the working architect; but your drawings, and some of the works you have executed showed what you were capable of doing in the way of practical architecture. It is, therefore, not in that capacity that this medal has been awarded to you. It is for your patient, zealous industry and power as an architectural historian, and for the faithfulness, ability and truthfulness with which you have fulfilled the task you undertook, that you now receive it. I am happy to say, in the present case, as in almost every other, Her Majesty has been pleased graciously to signify her cordial approval of the presentation we are now about to make. It cannot be necessary for me in this room, in the presence of English architects, and in presence also of the works which Mr. Fergusson has contributed to the history of our art or to its progress, to pass any eulogium upon his merits to this distinction. If I may be allowed to use the old quotation, "*si monumentum requiris, circumspice*"—I will not finish it—but I would say "look on this table: for here, I believe, are all his works, or if not I am sure Mr. Fergusson would wish they should all be here.

And it is not alone for his architectural researches that we are indebted to Mr. Fergusson, but we are greatly indebted to him for the labour he has bestowed, and the instruction he has imparted upon a subject which is one of deep interest to every member of the community, viz.: our national defences. As a Member of the Royal Commission on the Defences of the Country, Mr. Fergusson's labours have been fully appreciated by the Government. The high honour conferred upon him recently at Oxford shows the feeling entertained by the learned bodies of the University of his

varied powers, and his appointment to the office of Secretary to the Commissioners of Her Majesty's Works and Public Buildings, I think reflects the greatest credit upon the late Chief Commissioner Mr. Layard. I am sure that appointment was one which was universally approved by the profession and the public at large, and we have felt excessive regret that circumstances should have induced Mr. Fergusson to resign that appointment. It is not for me to ask Mr. Fergusson to listen to a long speech from me: but I venture to express a hope that he will be good enough to favour the meeting with a brief history of the circumstances under which he was first led to turn his attention to matters so interesting to us. I will not detain you further than to request Mr. Fergusson to accept in the name of the Institute the Royal Gold Medal, and I am sure you will all join me in the sincere hope that he may long live to wear it. (Great applause).

Mr. FERGUSSON, Fellow (who was received with loud applause) said.—Mr. President and Gentlemen, although I cannot but feel extremely flattered and gratified by the presentatation of this medal, and by the kind manner in which you have received me to-night, I will not trouble you with any laboured expressions of feelings which are usual on such an occasion; but if you will allow me—at the risk of being somewhat egotistical, and perhaps one may be pardoned for being egotistical on an occasion like this—I will at once, and with great pleasure, comply with the wish expressed by your President, that I would explain how I came first to take to that course of life which has resulted in the flattering mark of distinction which I have received at your hands to-night, and in so doing I will also explain why I feel more than ordinarily gratified by the honour which has been conferred upon me. To begin, then, I was, I may say, born an architect; from my boyhood, architecture was the pleasure and delight of my life, and my one great ambition was to be an architect; but being not the master of my own fate, I was destined for the counting house. I bore that with equanimity, because I saw that the counting-house might be the means of leading me to India, and I was in hopes that I should be able when in India to study the architecture of that country, and to solve some of the mysteries which hung over it. During my ten years' residence in India I was brought into contact with men who were erecting buildings in what I believed to be the mode of the Middle Ages. I saw men working in true styles, as true architects worked in those days, and I thought I had really got at the secret of the art, when I came to the determination to follow the original ambition of my life and to become an architect. But before doing so I reflected; and there were two considerations in particular which made me pause; the first was that architecture in this country was not treated, whether by the Government or by the judges of competitions or by the public, in the manner in which I considered it ought to be, simply because the upper classes in this country did not appreciate the art itself or the position of the professors of that art, and I wished to avoid exposing myself to the treatment which architects were too often exposed to. In the second place, I discovered that my principles of architecture were opposed not only to the practice of the architects of the country, but to the general feeling. What I believed was that the copying system—the copying of Italian and Greek architecture—was a mistake, and I was not prepared to follow that system; and I felt that, holding this strong difference of opinion to that of the profession generally, my prospects of employment as an architect were very small indeed.

Having come to these conclusions, I determined to abandon the idea of becoming a practising architect, and devoted myself thenceforward to the literature of the art. I thought I might perhaps be able to put architecture in a truer light before the public, and in that way probably do more good than by attempting to practise myself. In consequence, I set myself to write these works; they have been written not with the view to enrich architecture, but to teach the general public what architecture was, and to lead, if possible, to correcter views and higher appreciation of the art, as a real, living and important art. How far I may have succeeded in that I cannot say, because it must take time: but the one object I have had has been

to place the art in a popular and straightforward manner before the public, and to try to get them to believe in it and to appreciate what was due to it. In doing this I believe I have to some extent been misunderstood. I held then, as I do still, what may be considered strong opinions with regard to the general practice of architecture. On what I call the copying system I have expressed myself strongly, and have been misunderstood. I do not complain, because no man can put himself in opposition to a body of men without treading upon people's toes. But what makes me prize this medal more than anything else is, that I have reason to believe that gentlemen begin to see that I have been actuated in what I have written by no other motive than the good of the profession; and the presentation I have received this evening I esteem as an evidence that these motives have to some extent been recognized by this large body of the profession. In that sense, Mr. President and gentlemen, I feel particularly grateful to you; but without saying more with regard to myself, I should like before I sit down to state in a very few words what my own views are in the matter of architecture—what I believe to be its origin and its end. I have in this room heard eminent men recommend students to fill their books with copies of works, so as to have materials for labour hereafter. My own advice would be, copy till you learn to appreciate and know what has been done, but when you begin to practise leave your copy books and think for yourselves, and think only; for I feel convinced it is only when a man thinks he can arrange his building best and make it convenient for the purpose for which it is intended, and ornament it most appropriately for the age in which he lives. It is then only that architecture will be a living art. Amongst the books that are before you there are two volumes treating of architecture from the time of the Egyptians down to the building of St. Peter's. The whole of those buildings are beautiful and appropriate to their purposes. The third volume contains the styles since the building of St. Peter's to the present day, and of them I may say there is scarcely a work which has been really satisfactory or permanently pleasing and beautiful. On that broad induction, therefore, I say, unless you go back to the real, earnest style, you cannot make a building appropriate to the day or permanently pleasing. That is the theory I have inducted; I have done it honestly and earnestly, and I feel extremely gratified at this time to receive this medal, which I accept as a testimony on your part that my motives in what I have done have at least been straightforward and honest. I thank you very sincerely for the award of this medal, I assure you I shall always esteem it as one of the most gratifying testimonials I have ever received; and I shall value it accordingly. (Loud applause.)

The President having then presented the Soane Medallion, the Institute Medals and Student's Prizes in Books to the gentlemen whose name have been previously announced, invited Mr. J. P. Seddon to read his paper.

ON THE UNIVERSITY COLLEGE OF WALES AND OTHER BUILDINGS AT AND NEAR ABERYSTWITH.

By John P. Seddon, Hon. Sec.

The University College, Aberystwith.

A Memorial of the Committee of the proposed University College of Wales to the Right Honorable the Lords Commissioners of her Majesty's Treasury, praying for a grant towards the purchase-money and completion of the College buildings, and also an annual grant towards the salaries of professors, is now under consideration of the Government, and strong hopes are entertained of success in the establishment of the Institution. This, therefore, is not an inopportune moment for bringing before this Institute a statement as to the present condition of the building, and for describing the manner in which I intended to finish it.

I have been repeatedly assured by the Committee who purchased the building under my advice, that I should be employed to finish it, and that my designs should not be deviated from. If this assurance be fulfilled, I should hope to be able to maintain the general character as I present it to you on this occasion, although to suit its altered requirements and to study economy as needed, some modifications, particularly of the interior, will be necessary. Should, however, this promise not be carried out, and my hope of being allowed to bring my own work to completion frustrated, it will at any rate have been some satisfaction to me to have been able to have placed before my professional brethren a record of my design in its integrity. It will be necessary, in order that this may be understood, to give a brief sketch of the history of the structure, which was originally intended for quite another purpose than that to which it is now proposed to devote it.

In the spring of the year 1864 I was consulted by Mr. Thomas Savin (to whose energy Wales is indebted largely for railway accommodation) about some proposed works at Towyn in North Wales, and the completion of an unfinished hotel at Borth. While engaged upon this business I was asked by that gentleman to go on to Aberystwith, and to view the premises known then as Castle House, which he had just purchased in order to convert into an hotel, and to which he desired at once to add a large room to serve as a public restaurant, with a flat roof above to form a promenade overlooking the sea.

I found the mansion a curious and interesting one. It had been built by Mr. Nash, the late eminent architect, for Sir Uvedale Price (author of the well-known work on "The Picturesque"). It consisted of a triangular structure with an octagonal tower at each corner, and a polygonal bay projecting from the entrance side and a circular one on that facing the sea, while a number of lower buildings stretched from the third side towards the south upon an irregular strip of ground that lay between the cliff in front and a public road at the back. In the course of that day I prepared a sketch for this public room, not very dissimilar as to plan, from that which has since been built. In the evening Mr. Savin examined and approved this, and desired me to lay out the foundations the next morning, there being no time to be lost, as he wished the new wing to be in readiness for the approaching season. This I accordingly did, and a number of men having been at once set to work upon the necessary excavations, I returned to town to prepare and send down the requisite working drawings.

Shortly afterwards I received amended instructions to the effect that another story was to be added, in order to provide a number of bed rooms above the large room on the ground floor, and to give enlarged kitchen accommodation in the rear. At the same time I was informed that the materials that

I had selected for the work could not be obtained in time, and that the building was already being proceeded with in ordinary brickwork, which it was proposed to cover over with cement afterwards. In consequence, I then designed the south wing, with its upper story in timber-framed construction, with the panels filled in with $4\frac{1}{2}$ in. brickwork covered with Portland cement, and decorated with incised and colored lines and patterns. Within, and clear of this framing, I placed a thicker brick wall, leaving a clear vacant space between to ensure dryness. This additional thickness was required to obtain the requisite stability for the flooring which was to form the promenade above.

The south wing then consisted of, on the ground floor: the public dining room, 96 ft. long by about 30 ft. wide, having eight polygonal bay windows towards the sea, and a semi-circular recess on the opposite side, intended as a bar, and divided from the main room by an arcade of three arches upon marble columns. At the extreme southern end was another polygonal room, in the portion carried up as a tower, which increased the length of the vista to 115 feet. The space left me upon which to contrive the kitchen department was very limited and irregular. Under this portion, therefore, I made a basement communicating with the ground floor by a lift and two staircases, and I was able to obtain a mezzanine floor except over the kitchen itself. This latter was carried up a considerable height, with an open roof and lantern for ventilation. The utmost was made of the space thus arranged by Messrs. Longden, of Sheffield, to whom I entrusted the fitting up of the whole of this department.

In the principal room on the ground floor were two semi-circular hooded fire-places, arranged with double shafts to the chimneys, the inner to convey the smoke away and the outer for ventilation. This latter object was also efficiently assisted by the use throughout of Mr. Hammond's system of ventilating gaseliers, in the form of brackets carrying the products of combustion into flues. This provision was rendered necessary in consequence of the comparatively limited height of the apartment, which I was instructed to keep down so as not to prejudice Castle House itself, the raising of which was not then contemplated.

The first floor having to be sub-divided into numerous bed rooms, its construction was arranged by throwing a series of transverse queen-trussed partitions as deep as the height of the story, and placed at equal distances across the space of the large room below. The corridor passed through the centre of these, between the queen posts of the trusses. The longitudinal partitions were also framed as a succession of similar smaller trusses, resting upon the larger ones, and having the doorways to the several rooms between their queen posts. Each bed room thus formed on the seaward side was provided with a wooden balcony with a pavement of encaustic tiles. These balconies almost overhung the cliff, and commanded extensive views of Cardigan Bay and its coasts. The glazing of the upper sashes of all the windows of this wing was of an ornamental character, but the lower sashes were filled with plate glass, so that the view might not be intercepted. In the tower at the south end, an octagon sitting-room was provided with a writing closet in the turret adjoining, under the stairs leading up to the floor above; to this room two balconies were also added. On the second floor was the promenade referred to, the floor of which was covered with Seyssel asphalte. At the back of it was a part roofed over and enclosed as a corridor, and this communicated with a room in the octagonal end tower.

Access to this promenade was obtained by three separate staircases. The one already mentioned from the first floor, one direct from the large public room on the ground floor, and one from the waiters' department; there was also a lift from the kitchen communicating with each floor above.

The whole of this flat roof has since been covered in by the Committee of the College after consultation with me as to the advisability and general method of doing it, and the vast apartment thus gained will, doubtless, be of great use to the Institution as a place for recreation for the students. This, however, is one of some works recently executed over which unfortunately I have not been allowed to

exercise any control, and which I regret to say has not been carried out in all respects as I should wish with respect to the general effect of the building, and many of the details are certainly not such as I should have designed.

All the chimney stacks upon this Southern wing are of Ransome's patent stone, which seems to have stood well the trying test of the sea air to which they have now been exposed for some years.

From the above description it will be seen that when this Southern wing was built, that on the Northern side of the original structure had not been contemplated, nor the raising and casing of the central and original portion of the structure. This is the reason that it was kept down in height, as its supposed comparatively temporary purpose was of the peculiar nature of its construction.

In the autumn of the same year I was again sent for by my client, Mr. Savin, and instructed to proceed with all possible speed with a still larger wing on the Northern side of Castle House. This was to include a suite of public drawing rooms, a public bar and billiard rooms, with numerous private sitting rooms and bed rooms. The establishment was designed to afford accommodation for a large number of persons on the American system of living in common, while the original Castle House could be retained for the more private use of a single family, as also other private apartments to be provided, and yet all served from the same kitchen and waiting department. The hotel thus arranged was to be one of a series along the coast of North Wales in connection with the Welsh Coast Railway; that already mentioned at Borth, and another subsequently enlarged at Aberdovey, were also in connection with the same scheme. This north wing when commenced was only intended to be three stories in height, but as the work proceeded, the instructions given to me varied considerably, so that at last it attained to six stories. This is the reason that some of the internal areas appear small in proportion to the building as it stands, but no rooms of importance look into the Courts.

I had some difficulty under the circumstances in controlling the massing of the buildings so that they might group satisfactorily as a whole; the more so, as from the haste with which I was obliged to press on the work and keep 500 men in full employment, I never was able to make any complete drawings. A rough wooden model was all that I could prepare for general guidance, with the requisite working drawings for details as they were required.

The materials which I was now able to command were in every way preferable to what they had been in the case of the former wing. The stone used for the walling was a cinnamon colored sandstone from a quarry belonging to Mr. Savin near Cefn, that employed for the dressings was the best description of Bath stone. The shafts of the columns, which act throughout as mullions to the windows, were of a delicate, bluish tinted sandstone from Hanam near Bristol, but at the back of the building they are alternately of a red conglomerate from Radyr near Cardiff, and this latter stone, which is of great hardness, has been generally used for the steps.

In planning this Northern wing, the principal point I had to consider was concentration for the purposes of service and supervision. With this in view, and to accommodate the irregularity of the site, I arranged the portion next to old Castle House with the bar apartment curved on the inner side, the general corridor following the curve, with the entrance, the main staircase and passage to servants' staircase immediately opposite. The curvature alluded to gave complete command to the occupants of the bar not only of these, but also of the main corridor down the north new wing, the entrance into the old central building, the separate special staircase to the billiard department, and the lift which served all the upper floors.

The large public drawing room was placed at the extreme northern end, and the space it occupies is about 80 feet by 40. Being irregular on plan, it is divided into a rectangle of 64 by 32 feet, with trefoiled shaped end towards the sea-front, and a segmental apse projects from the other end, while an

aisle, as it were, on the other side is divided off by an arcade of four arches carried by marble columns, and each bay of this aisle is treated as a separate recess, and vaulted with stone ribs.

A sort of clerestory range of circular traceried windows is carried along the eastern end and round the apse of this apartment. A smaller drawing room communicates with this larger one by means of folding doors. Two other sitting rooms facing the sea, 25 feet square each, have polygonal bay windows. Between them and the smaller drawing room is a vaulted passage way, giving access to the terrace from the hall which forms an ante-space to the large drawing room. Opposite this entrance is the position for a secondary staircase, which, continued from the bottom to the top of the building, communicates readily with both of the blocks of which this north wing is composed by means of an intermediate tower, in which are situated closets and lavatories for every floor.

The hall which forms the ante-space to the large drawing room was intended to be carried up to the roof, and lighted from the top, and to have galleries round it to give access to the upper floors.

There are three floors of bed rooms at the back to two floors of the sitting-rooms facing the sea, and to one floor of the great drawing-room, which of course seriously complicated the arrangement. The suite of drawing rooms on the first-floor over the two 25 feet square rooms and small adjoining one being entered at the ends, the corridor behind them was intended to be carried up three floors with intermediate galleries only for access to the bed rooms behind. By this means light would be thrown into the corridor from skylights over the hall and curved corridor.

The billiard room is situated over the bar apartment, and is made to curve outwards as well as inwards, the projection over the floor below being carried by arches thrown from the buttresses between the windows. The size of the room, 48 by 24 feet in clear, gives proper space for three billiard tables and the curved recesses on each side ample room for spectators. The recesses are divided off by arcades of three arches resting upon triple groups of columns. The special staircase for this department is continued upwards to the gallery over the entrance, and a room appropriated for smoking in the tower above the vaulting of the principal staircase.

The principal staircase leads only to the first floor on to the curved corridor, whence another oak flight continues to the floor above. The former is of stone within the great tower, and is arranged with a straight flight up to a landing which has a segmental apsidal projection from it, in which I intended to place a fountain. The staircase is then continued right and left round the two columns which support the vaulting. The servants' staircase is carried up in the turret adjoining the great tower, and is of stone throughout. By its position it serves readily every floor of each block of building in this north wing.

The position of the entrance rendered necessary a somewhat peculiar treatment of the carriage porch. Had this been arranged upon the ordinary rectangular method, it would have been difficult to have driven through it clear of the angle of the old house. The triangular treatment of this feature as shewn on the drawings was the result of the endeavour to avoid this difficulty, and nothing is easier now than to drive a coach and four right up to the doorway, and ample shelter is provided for the occupants of carriages.

The tower in which the principal staircase is situated was designed to be as high as ten stories, marked by the revolution of the stairs in the turret adjoining, and the turret would be carried up an additional one to give access to each floor and to the roof of the great tower, whence a splendid view of the coast and mountain scenery as far as Snowdon would be obtained. It is now contemplated to place an observatory upon the top of it. The plan of the tower is trefoiled on the outside, but follows the curve of the corridor on the inside until it clears the roof, after which it is square.

The original terrace wall which had been built against the cliff in front of Castle House premises was very narrow, and the space enclosed very limited. To remedy these defects a new sea-wall was

built along the whole length of the southern wing, which nearly doubled the width of the terrace. In front of the central old building, however, the bastion was left as it was, the space there being greater; but the entire frontage before the north wing was rebuilt and advanced considerably on to the shore, thus gaining about half an acre of additional ground. This sea-wall is arranged as a large triangle upon plan, turning as it rises into a trefoil shape, the angle losing itself as a spur on the face of the centre of the trefoil. A circular bastion was also built in front of and concentric with the bay of the large drawing room. The construction of this work was somewhat difficult; an immense strength of men was put upon the work, and it was effected between spring tides in masonry set with hydraulic lime mortar.

Some of the internal floors may be noticed as having been constructed in a somewhat peculiar manner, particularly that under the billiard room, and which was needed to be especially rigid. It may be described as double-framed, the lower framing being ornamental, and its construction shown and decorated. There being ample thickness and weight of walling to resist any thrust, the strength of the arrangement is great, and the effect which is that of a flat description of wooden vaulting, is agreeable. The floors of several of the sitting rooms is of the same class of construction, but varied in detail. Those of the small drawing and the 25-foot square sitting rooms are of this character, and that of the large drawing room was designed to be so; but this has not as yet been executed.

As to the cost of the structure, I am sorry to be unable to give you any precise information, as I never had any control over it, Mr. Savin having been his own contractor throughout. It is said, however, that the entire expenditure by that gentleman on the purchase of Castle House and the subsequent alterations and additions was about £80,000. In the year 1866, the building passed, in an unfinished state, into the hands of the present proprietors, the Committee of the proposed University of Wales. A set of photographs of the structure in the condition it was then in was presented by me some time since to this Institute, and are preserved in the library. Although the purpose to which the building is now proposed to be devoted is a very different one, it is curious and fortunate that the future requirements will not be very dissimilar from those of my previous client. The public rooms will be needed as meeting halls and lecture rooms, and the entrance-hall as a museum. The old castle house in the centre will serve as a residence for the Principal of the establishment, and the public dining room, with its culinary department, will need no change of purpose or arrangement, while the numerous sleeping rooms are just what would be required by the various masters and pupils of the College, and an ample work or recreation room exists, as has been explained, on the upper story of the south wing.

No locality could possibly be more healthy or delightful for the purpose of such an educational institution, and Aberystwith is so centrally situated in the principality that it would appear to be remarkably well fitted as a site for such a university.

I may perhaps be allowed to express a hope, under the circumstances, that the Committee may be induced to resolve upon finishing the building in the general character in which it has been commenced and carried out so far, and not to spoil it by injudicious economy. Having purchased it for only £10,000., a sum evidently far below the original cost, they have expended since then about another £1,000, and about £7,000. more would, according to an estimate from a substantial contractor, that I laid before the Committee some time ago, complete the north wing according to the general character of my design, as I now submit it to you.

Llanbadern Fawr Church.

The present parish church, but anciently the Cathedral of Llanbadern Fawr, stands about a mile inland from Aberystwith, on the north road to Borth. It is a structure of interest from its special Welsh character, its great size, and extreme simplicity. Its Welsh characteristics are noticeable by

comparison of its features with those of other contemporary buildings in the principality, such as the neighbouring church at Towyn, the Priory and Christchurch at Brecon, Ewenny Abbey, Glamorganshire, and others. External plainness, one of their characteristics, is prominent in this example, and admirably in harmony with the scenery around it. All the openings are simple lancets of good proportion, with their outer edges chamfered, and the inside deeply splayed. In each of the west and south gabled ends these lancets are arranged in a group of three, widely separated, and one much higher than the rest. This is a quaint arrangement, which I have met with in the east gabled end of Holmer chancel, near Hereford.

The Plan of Llanbadern Fawr Church is a Latin cross without aisles, and with a massive tower over the intersection. The massiveness of this will be appreciated when I stated that 40 feet is the width externally of each arm of the cross, and therefore of the tower as well. The greater part of the structure is of the thirteenth century, but it has to a considerable extent been rebuilt upon the original plan at subsequent periods, apparently after severe injury from fire probably with violence, during some of the troublous times that Wales has seen.

I cannot but think that many richer features have disappeared from the interior of the Church during such rebuildings, for the admirable degree of finish in those masonry dressings, which are original, and the elaborate character of the beautiful southern doorway would lead one to expect that, together with the reserved plainness of the exterior, this church would have combined some of the richer internal character of its compeers at Brecon and elsewhere. As it is, with the exception of the doorway named, but little architectural detail remains within; the crux piers and arches have neither chamfer nor moulding, nor dressed stonework, and I believe are, with the superstructure which has worked stones built up randomwise in its walls, the result of some later clumsy rebuilding, to which date all its roofs were also referable.

The church had fallen during the lapse of centuries into a dangerously dilapidated condition; the roofs had decayed, and thrust out the walls, so that those of the nave overhung their base in parts 15 inches, and were rent in numerous directions. The nave has recently been restored under my directions. As much of the old walling as it was practicable to retain intact was left, and the rest rebuilt. A new roof has been put on to it, with a boarded ceiling, with moulded cornice and ribs, with carved bosses at the intersections.

The porch, which was not old and was of a poor character, has been rebuilt; and, fortunately, the southern doorway within it was preserved just as it was, without repair, although many of the dressings are sadly weatherworn. It has three triple groups of shafts to the jambs and richly moulded archivolts, and the capitals to the columns are worked into a simple but effective belt of carving. The character of these details is very similar to the Early English work at Llandaff Cathedral, and of that curious arcade from the once famous Abbey of Cwm Hir, that has got so strangely into the Church at Llanidloes.

During the work to the nave some curious fragments of successive polychromatic and pictorial decorations were discovered upon different coats of whitewash, but these were so fragmentary that it proved impossible to preserve any of them. I have on a former occasion called the attention of this Institute to a drawing which I had made by Mr. E. S. Cole, the architectural artist, of two colossal figures of St. Christopher and St. Peter, one of which seems to have been painted over the other, and only part of each of which it was possible to uncover.

What is requisite to the rest of the church remains to be done, and what I propose is shown by the drawings before you. The only alteration of moment is the substitution of a larger spire for the present small and decayed one, which cannot be original. This portion of the design is therefore open to criticism. At present there being no outlet for the sound of the bells but the small window in the

tower, they are hung so low that a bell-ringing stage is suspended below the apex of the crux arches, and my main object in proposing a new and larger spire is that the bells may be raised and enable to speak through the lucarnes of the new spire, and the stage for the ringers put where it must have been intended to be, or at any rate, must hereafter be—on the floor clear above the arches of the crux, as the bells cannot possibly be rung from the floor of the church.

Victoria Terrace, Aberystwith.

The next work that I propose to bring before you is the Victoria Terrace, at the opposite end of the Parade fronting the sea at Aberystwith to that where the College is situated. The site extends from the Queen's Hotel, built some years since from the designs of our Fellow, Mr. C. F. Hayward, and Mr. H. B. Davis, joint architects, nearly up to the promontory which projects into the sea on the north side of the town. The Corporation of the town have recently expended about £ 2,000. in building a sea-wall with circular bastions at intervals, and in forming an esplanade in front of this site; and they commissioned me to prepare the requisite plans for the Terrace itself, so that builders who may take leases might be compelled to conform to my designs. Three of these houses have already been erected, and will be completed in readiness for the coming season. Mr. Thomas Williams, of Canton, near Cardiff, is the lessee. The end house, at the angle next the Queen's Hotel, is six stories high, and the adjoining two five stories.

The plans which I lay before you show how I have endeavoured to meet the peculiar requirements of a sea-side place, by making each floor contain a sitting room, bed and dressing rooms, and to be as complete in itself as possible. It is intended to diversify the houses, and to introduce among them several larger ones, with rooms on each side of the entrance, and the plans of the fourth and fifth houses of the Terrace, which I exhibit also, may be taken as examples. In selecting the materials with which to construct this terrace, it appeared to me that it would be desirable to introduce into the work some richer colouring than that of the existing Parade, or indeed than that usually employed in sea-side towns. The too frequent use of cement as a surface to exclude damp generally gives a sad and monotonous appearance to the frontages of most of our sea-side places.

The old houses of Aberystwith only luxuriate in varieties of yellow dab or more sombrely tinted washes, but the Queen's Hotel, with which my work will come into immediate contrast, is faced with the local purplish stone, relieved with freestone dressings.

In consideration of these circumstances, I chose a rich red brick from the neighbourhood of Cardiff, as the material for the general groundwork. This is so used up to the underside of the topmost stories where I have changed it for a ground of buff brickwork, and I have relieved the former by the introduction of blue Staffordshire bricks, and the latter by carrying up some of the red into it. The columns forming the mullions of the windows are, like those of the College, of various delicately tinted sandstones; the capitals are all treated differently, with a small amount of carving. As Aberystwith faces westward, the Parade is mostly in shade during the heat of the day, but towards evening it catches the rays of the setting sun. I hope, therefore, that the effect of this terrace will be brilliant at a time of day when such can be tolerated.

I understand that the cost of the three houses, nearly completed, will be about £ 5,200, that is to say, about £ 2,000 for the corner house, and £ 1,600 for each of the smaller houses.

Mansion at Abermaide.

The drawings for this work, a mansion in course of erection at Abermaide, about four miles from Aberystwith, on the southern road towards Aberayron, need little description.

I submit them on this occasion because the detail resembles in many points that that I have used

at the College in Aberystwith, but modified so as to suit a structure of smaller size and less important character. I am under the same difficulty with regard to giving you any idea of its cost as in that case, since my esteemed client, Lewis Pugh Pugh, Esq. is building this himself. The material of the walling employed is the local purplish stone, with dressings from Doulting, worked at the quarry.

The entrance hall fireplace has been wrought on the spot out of Mr. Pugh's own stone, to give the masons an opportunity of showing what they could do with it; and though the mouldings and detail are elaborate, and the stone excessively hard, the result is highly satisfactory. The carriage porch is supported by columns with polished shafts of Shap granite, a most effective and ornamental material, which I considered would harmonize with the deep tint of the walling better than lighter stone. A basement having been made under the whole house, the opportunity afforded by it has been taken to carry down all the flues of the principal rooms, so that they may be swept from below. Besides the usual cellarage and larder provided in it, there is a large ice-house, heating chamber, laundry, and drying-room. The construction of the floors over the principal rooms on the ground floor are of the ornamental double framed character, similar to those described in my account of the College, varied in arrangement and detail.

The PRESIDENT.—We are very much obliged to Mr. Seddon for the kind way in which he has stepped in to fill the unfortunate *hiatus* occasioned by his brother's illness. He has described a work of great difficulty and great anxiety, and I hope it will be his task to carry it to a successful issue. I have very great pleasure in proposing a vote of thanks to Mr. Seddon for his paper. If any gentleman has any remarks to offer we shall be happy to hear them, and I am quite sure Mr. Seddon will be glad to reply to any inquiries that may be put to him.

Mr. C. F. HAYWARD, Fellow—I must bear my testimony to the extreme beauty of some of the details of this large building described by Mr. Seddon, now proposed to be utilised as the University for Wales, and I feel the more bound to do this, knowing as I do some of the difficulties with which he has had to contend, and when we hear that he had no control over the expenditure, and was obliged to carry out the work in great part without regular drawings, it is remarkable that so fine a group, as well as so clever an arrangement of plan, is the result. In seconding the vote of thanks I felt I could do no less than thus bear testimony to the truthfulness and modesty with which Mr. Seddon has described his work, and I sincerely trust he may have the completion of it entrusted to him.

The PRESIDENT.—I think we have some members of the Committee of this College present, and we should be happy to hear some remarks from them.

Mr. LEWIS ANGELL, Fellow.—As one of the Executive Committee of the University College for Wales, and also as a member of this Institute, I join with great pleasure in the thanks that have been proposed to Mr. Seddon. I had an opportunity last autumn of going over the College buildings, and was much struck with the boldness and character of the work, and looking at all the details one would almost think that Mr. Seddon had a presentiment of the ultimate purpose to which the building was to be appropriated. Admirable as would have been the arrangements for an hotel, they are more suitable, I think, for a Collegiate Institution. It will be a glorious thing for Wales to obtain such an Institution and such a building for its habitation. As a member of the University Committee of recent appointment, I have been no party to the treatment which Mr. Seddon has alluded to. I hope funds will be obtained and that Mr. Seddon will have to complete the bold design which he has detailed to us this evening. The cost has been stated at £80,000, but the University Committee obtained it for £10,000: I hope Mr. Seddon had his commission upon the larger amount.

The vote of thanks having been unanimously accorded to Mr. Seddon, the meeting adjourned.

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At the Ordinary General Meeting, held on Monday, 22nd May, 1871, the following Paper was read—THOS. H. WYATT, President, in the Chair:—

ON THE DECORATION OF ST. PAUL'S CATHEDRAL.

By F. C. PENROSE, M.A., Fellow.

THE embellishment of St. Paul's Cathedral, though not a new subject, is one, nevertheless, which is most fitting for the consideration of this Institute. When I first accepted the invitation made to me to bring it before you during this season, I entertained the hope that I might be able to illustrate my paper with various designs. But this wish I have not been able to carry out for these reasons.

The Committee who have undertaken to assist the Dean and Chapter in this great work have had their attention directed to other branches of the subject, and have not yet come to any decision on matters affecting the decoration, consequently I shall not be able to give you any of the views of the Committee; and, inasmuch as my own attention has been in a very great measure withdrawn from the designs for the decoration to other objects, I am not nearly so well prepared to address you now as I should have been if my time during the last six months could have been exclusively or largely devoted to it,—and this explains also why I have thought it best not to produce here this evening any of the many studies I have made with reference to it. This, however, I hope I may be able to do on a future occasion; and shall now endeavour to convey to you in words some definite notion of the views I am trying, however imperfectly, to realize, with the view of promoting this great work, and whether they be right or wrong they will doubtless, considering the importance of the end proposed, provoke a discussion here which will be heartily welcomed by our Committee and all connected with it, and which cannot fail to be of much service.

It is curious that I feel myself obliged to begin with asking the question whether it is fit that St. Paul's should be decorated at all. It is, to be sure, rather late to ask such a question, when several thousand pounds have already been expended on mosaics, marble, gilding, and painted glass. Moreover, it is in evidence that the great architect himself contemplated a mosaic painting in the dome, pictures on the vaults, and coloured marbles for his apse and especially his altarpiece or baldachino, and that a succession of authorities at various times have pronounced in favour of attempting it—Sir Joshua Reynolds and the Academicians of his day—Mr. Cockerell and Sir Charles Barry—Mr. Petit and Mr. Winston more recently—and the highly distinguished members of the present Committee, some of whom are here present this evening.

But a most truly eminent architect has recently, as it were, moved the previous question and maintained, if I understand him rightly, that the walls, the vaults, and the windows should be left uncoloured, and all the expenditure be bestowed upon elaborating the church furniture, screens, and pavement.

On this subject I am very far from venturing to assert that St. Paul's has yet benefitted from the colour bestowed upon it. A little colour, like a little learning, is a dangerous thing. Who does not know the disappointing effect produced when a carefully outlined pencil or monotint drawing has had half an hour's work of colour wash upon it, and which must then for lack of opportunity to finish it be put aside. The drawing which had been a charming work in pencil or neutral tint is spoilt unless the additional hours upon hours be added, which are necessary to bring out the full splendour of the work in colour. But we should be wrong in saying that the drawing must necessarily be best in pencil and that the attempt to colour it was a mistake.

I think, however, I shall have your general assent that the great question is not whether it should be done, but *how* it should be done. It would be well at this stage of the enquiry to see what can be gleaned of Sir Christopher Wren's views on the ornamentation of the Cathedral.

In the *Parentalia*, p. 291, we read:—"In the aisles the lesser cupolas are both ways cut in semi-circular sections and altogether make a graceful geometrical form, distinguished by circular wreaths, which is the horizontal section of the cupola; for the hemisphere may be cut all manner of ways into circular sections, and the arches and wreaths, being of stone carved, the spandrils between are of sound brick, invested with stucco of cockleshell lime, and which, having large planes between the stone ribs, are capable of further ornaments of painting if required. The inside of the whole cupola is painted and richly decorated by an eminent English artist, Sir James Thornhill, containing in eight compartments the histories of St. Paul. In the crown of the vault, as in the Pantheon, is a circular opening, by which not only the lantern transmits light, but the inside ornaments of the painted and gilded cone display a new and agreeable scene."

In a note on the last paragraph we find the following information: "The judgement of the surveyor was originally, instead of painting in the manner it is now performed, to have beautified the inside of the cupola with the more durable ornament of *mosaick* work as is nobly executed in the cupola of St. Peter's at Rome, which strikes the eye of the beholder with a most magnificent and splendid appearance, and which, without the least decay of colours, is as lasting as marble or the building itself. For this purpose he had projected to have procured from Italy four of the most eminent artists in that profession. But as this art was a great novelty in England, and not generally apprehended, it did not receive the encouragement it deserved. It was imagined also the expense would prove too great and the time very long in execution; but though these and all objections were fully answered, yet this excellent design was no further pursued. The painting and gilding of the architecture of the east end of the Church over the communion table was intended only to serve the present occasion till such time as materials could have been procured for a magnificent design of an altar, consisting of four pillars of the richest Greek marbles, supporting a canopy hemi-spherical, with proper decorations of architecture and sculpture, for which the respective drawings and a model were prepared. Information and particular descriptions of certain blocks of marble were once sent to the Right Reverend Dr. Compton, Bishop of London, from a Levantine merchant in Holland, and communicated to the surveyor, but unluckily the colours and scantling did not answer his purpose, so it rested in expectance of a fitter opportunity; else probably this curious and stately design had been finished at the same time as the main fabrick."

I believe there is now a general concurrence of opinion in our Committee (although, indeed, I am not authorized as yet in speaking in their names), that the proper material for almost all the coloured pictorial decoration is mosaic, and that if it cannot yet be afforded it would be better to wait until it could be carried out, than to adopt an inferior material. I hope that this opinion may also find favour here. With myself this is a conviction of fifteen years' standing. Before any modern mosaic had been talked of in England I had seen that Signor Radi, of Murano (at the works since taken by Salviati), could produce the material, which again I found obtainable at Palermo (the Vatican manufactory being too expensive), and the reports I sent home to this effect led the late Dean of St. Paul's, in the first instance, and afterwards the Committee over which he presided, to commence the pictorial embellishment of the Cathedral by one of the spandrils of the dome, from a design by Mr. A. Stevens, since followed by another by Mr. Watts.

The brilliant and imperishable qualities of this material recommend it strongly for use in a London atmosphere, at least for all the important surfaces, and especially those which are concave, of which there are so many. It is not at all, however, out of place to enquire whether other kinds of painting or

ceramic work may not be very suitable for some of the subordinate and flat spaces, or for places where pictures may be admissible near the eye, for I much doubt if mosaic is to be recommended at distances from the eye less than 50 feet. There would not, however, I think, be many convenient positions for pictorial treatment at a less distance than this, and as for the nearer spaces they seem to offer themselves more appropriately for sculpture and for coloured marble decoration.

As I have the fullest conviction that ultimately the work of the decorative completion of St. Paul's will be carried out, I will venture to read what has been sketched out, a vision, as it were, of what may be seen some years hence. It is an extract from the Appendix to Dean Milman's work on St. Paul's.

"The object of primary importance with the Dean and Chapter, and with those who have co-operated with them during the last ten years in the completion of the interior of St. Paul's Cathedral, has been to enlarge its capacity and convenience for divine service. Secondarily to adorn it in a manner worthy of the noble framework of its architecture, and of the intentions of Sir Christopher Wren, whose general views in this respect have been recorded, although but little is known in detail of the manner in which he would have carried them out if he had not fallen in his latter days upon evil times and evil tongues.

"The first object appears to have been satisfactorily attained. The second, although up to this present time greatly impeded by want of funds, has been so far inaugurated as to insure, it may be hoped, its ultimate achievement. The coldness of the aspect of the interior was proverbial: it needed paintings, both on the walls and in the windows; marbles and gilding. In all these a commencement has been made. It is scarcely desirable that the interior of St. Paul's should rival St. Peter's at Rome in exuberance of ornament, but no one can doubt that a great deal of colour and rich material is requisite if it is to assert its proper place among the most remarkable buildings in the world. Towards attaining this end it has been kept in view that a little properly done is better than large surfaces of inferior ornament and, consequently, Munich windows, paintings in imperishable mosaic, and marbles of the choicest kinds have been used in preference to cheaper materials and more expeditious methods.

"The scheme in general may be thus sketched out. The interior of the cathedral, as it might appear in the imagination of the sanguine, presents itself thus: coming in at the great west door, we enter the nave, of which the original severity is not altogether subdued. Still, it is enlivened to some extent by inlaid marbles in the wall panels, and by the improved glazing of the windows on the north and south sides, into which some colour has been introduced, yet not so as to interfere with the admission of the full breadth of sunlight. The vaults are adorned with gilding and mosaic, and especially the large cupola over the westernmost bay of the nave has a mosaic painting representing, on a gold ground, one of the earlier miracles of our Lord. Right and left the beautiful western chapels, that on the north, used for early morning prayer, and the other (formerly the Bishop's consistory), now containing the elaborate and splendid monument to the Duke of Wellington, are richly ornamented with colour in like materials. Only a portion of the dome is as yet seen, but Mr. Watts' pictures of St. Mark and St. Luke, executed in mosaic on the spandrils of the great arches, invite the eye in that direction.

"Further eastwards the apse is brilliant with its six painted windows, while in the tribune itself is seen the marble baldachino which Sir Christopher Wren would himself have constructed if circumstances had been favorable.

"Advancing to the dome the eight large spandril pictures come into view—the four Evangelists designed by Mr. Watts, and the four major prophets by Mr. Stevens. Above the gilded rails of the whispering gallery an inscription, on a mosaic gold ground, taken from the words of St. Paul, surrounds the base of the dome. In the peristyle, statues have been placed in the empty niches, and in the dome itself is a great picture suggestive of the heavenly Jerusalem, which has taken the place of Sir James Thornhill's *grisaille* subjects.

"In the four semi-domes, at the intersections of the aisle, are representations of scenes taken from the Gospels, and at the extremity of the north transept is an internal porch displaying the inscription commemorative of Sir Christopher Wren:—'Lector, si monumentum requiris circumspice,' which was taken down from the old organ screen and has so long been waiting for restoration. A painted subject, from the life of St. Paul, fills the great window of the north transept, and the aisle windows at both ends are also painted. Thus the light at the end of each vista is subdued, whilst it is allowed to come in unobstructedly on the sides.

"Doubtless closer scrutiny will discover other details, and as it cannot be supposed but that many of the objects have been presented by private donors, there will be their armorial bearings and memorial inscriptions to lend an additional interest to the survey. Arriving at the choir, we find a rich, but low open screen has replaced the somewhat rude rails near the marble pulpit, and here, although we are sensible of a somewhat greater amount of elaboration and colour bestowed upon the walls and clerestory windows than in the nave or transept, yet the chief interest is centred in the apse.

"The six noble subjects in the painted windows embodying those six events of paramount moment to Christian faith, which are collected in the verses of our Litany:—'By thine agony and bloody sweat, by thy Cross and passion, by thy precious death and burial, by thy glorious resurrection and ascension, and by the coming of the Holy Ghost,'—are now near enough to be minutely examined. The details of the baldachino also are distinguishable, and we perceive behind it, and around the tribune, a design in marble intarsiatura, representing the Last Supper. If we should pass into the aisles of the choir we may expect to see richly painted windows at the ends, monuments and other decorations of the panels and vaults, though all subordinate to the greater concentration in the centre."

This was the programme ten years ago, and will, I think, be the programme still. These ideas were the foundations laid for such parts of the superstructure as could be raised with the limited means accorded to Dean Milman's Committee. Our present Dean, quite as anxious as his predecessor to see the Cathedral utilized and embellished, and working with a more numerous Committee, will not, I believe, be advised to alter materially the foundations thus prepared. I will read an extract from a printed prospectus or appeal put forward by the present Committee:—

"The better to illustrate the idea of the magnificence which has been imagined, let the entrance be supposed at the west end about to become the easiest access to the Cathedral. On passing through bronze doors richly charged with devices, the first most striking effect would be produced by the brilliant roof covered with mosaic patterns and rich with gold. The cupola immediately overhead, 40 feet in diameter, and the panels of the exquisite side chapels would be pictorially treated in the same material. The walls relieved with marble slabs and marble inlay; the pavement also and the windows enriched with colour must be so treated as to preserve a due regard for breadth of effect and the necessity in St. Paul's for a large amount of unobstructed sunlight, all panels to be filled with coloured marbles or sculpture, and no niche to be without its statue. The nave and transepts must, however, be in some respects subordinate to the choir.

"In the great dome, which has been happily called the very 'essence of the building,' the *grisaille* pictures of Sir James Thornhill cannot fail ultimately to give place to Sir Christopher Wren's cherished wish for mosaic pictures. And in addition to these the drum and the eight spandrils (the latter already commenced in mosaic) will afford grand scope for the highest efforts of art and magnificence.

"The roof of the choir should be a splendid and impressive work in mosaic, elaborate while massive and dignified in general effect, surpassing the richness of the rest of the Church. The windows in the apse will here also be more fully coloured; and the marbles, whether used structurally as replacing the stonework of the principal pilasters, or in panels and inlaid patterns on the walls and pavement, would

all be arranged so as to impart a fuller idea of sumptuousness. This must be especially the case with the ciborium, and the choir screen already referred to."

Holding themselves, however, quite at liberty to alter, even fundamentally, should they think fit, the recommendations of their predecessors, the Committee has taken the extremely judicious step of asking Mr. Burges to prepare an iconographical scheme to guide them in the selection of subjects for the embellishment of the different parts of the structure. Mr. Burges has fulfilled his commission with great assiduity, and, in a report of extreme perspicuity and value, has pointed out in detail the order of subjects which he recommends for the different parts of the Cathedral. He is, I believe, here to answer for himself; but so far as I am aware there is only one point (namely, the subject introduced into the western window) in which he desires to alter the order of the subjects introduced by the old Committee, which, though much less complete than his own, had been sketched out sufficiently to meet present requirements.

A copy of this report, by permission, I present to the Institute, and I have thus much enlarged on the general coincidence of Mr. Burges's Report with the ideas that had previously obtained acceptance as being evidence of the real convergence of an independent investigation and an independent mind. Further in his prefatory remarks, Mr. Burges refers to the style of architectural treatment which is most likely to be selected, and considers that some variety of the cinque-cento style would be on the whole the most convenient as compared with the more robust, but less pure style prevalent at the time St. Paul's was built. This is also strictly in accordance with all that has hitherto been done or proposed for execution.

Thus, there appear to be no divided counsels, and I think there is a strong persuasion that the road to a great success lies before us; but as the Committee has as yet come to no definite conclusion, it seems to me that the opinions of the members of this Institute could not be asked for at a more convenient juncture, whether such opinions should prove, as I hope, confirmatory of the views I am endeavouring to bring before you, or as indicating the propriety of further consideration.

I have now come to the point at which I believe I may venture on the authority of such churches as St. Mark's at Venice, St. Peter's at Rome, St. Andrea at Mantua, St. Boniface at Munich. The practice of such architects as Raphael, Michael Angelo, Sansovino, and the recorded wishes of our own Sir Christopher Wren, to dismiss as untenable the proposition that St. Paul's should not be ornamented with coloured walls and roofs—why, even the severe Escurial has its vaults enriched with frescoes! The questions then rather are where to begin, the style of treatment, the subject, the material, and the artists. There seem to be two places where, above all others, a commencement should be made, and which should, I think, be carried on *pari passu*.

One, the apse, as the completion of the sanctuary; the other, the dome. The apse windows, before many months are gone, will be filled with painted glass, and if the present ideas, identical moreover with Mr. Burges's iconography, should be carried out, a colossal figure of our Lord, surrounded by angels, would adorn the apse roof. The material being mosaic, and the selection of the artist will demand and receive the most conscientious consideration of the Committee.

As respects the dome, the passages which have been read from the *Parentalia* show clearly what was the judgement of Sir Christopher Wren with regard to this magnificent feature. He would have made it vie with St. Peter's at Rome in magnificence of ornament, as it does to a great degree in size.

I should be glad to be allowed to recall what I said on this subject in a paper read before this Institute in 1859. In speaking of the recent restoration of the *grisaille* pictures of Sir James Thornhill by Mr. E. T. Parris, I proceeded to say, without any deduction from the energy and success of Mr. Parris' work:—

"If, however, the present more ambitious views—perhaps rather dreams—dreams that, nevertheless, I hope, may work in the direction of their own fulfilment—had been entertained at the time of this restoration being proposed, it is probable that Sir James Thornhill's work, which, whatever its merits, must be pronounced only second-rate, would hardly have been followed and restored so scrupulously."

The dream here alluded to was Sir Christopher's own original wish—"the surveyor's judgment,"—and not the cheap, and if not nasty, yet second-rate performance of Sir James Thornhill, which he was obliged to put up with, after thus lamenting the failure of his own cherished ideal. "As for painting the cupola (he is writing to the Archbishop of Canterbury and Bishop of London in 1711), your Lordships know that it has been long in consideration, that I have no power left me concerning it, and that it is not resolved in what manner to do it, or whether at all." But now the time, I think, is not far off for inaugurating the great work of St. Paul's dome in mosaic. A few more thousand pounds added to the subscriptions already paid or promised—and is it too much to hope that London should show but one tithe of the zeal which has animated so many provincial cities, for that would suffice, or that some millionaire might offer this special gift?—at any rate, a few more thousand pounds will enable the Committee to complete this work effectually. London would then not need to be ashamed of the interior of her Cathedral; for, the dome once done, the rest can hardly fail of following as rapidly as it ought to be done. As to the nature of the design proper for this work, it is so essentially a part of the architecture that there can be no doubt but that an architect's mind ought to precede the painter's and arrange the form and details of the ribs and bands, the size of the panels and the scale of the figures, before the figure painter is introduced upon the work. The two minds may then properly act and react upon each other, but the architectural elements must not be subordinated to the pictorial, as it is, for instance, in Sir James Thornhill's work. The subject for the dome, *consensu omnium*, should be the state of the blessed, for which *motivi* may be sought for in the works of the great painters of the Renaissance. Conspicuously, by way of example, "The Worship of the Lamb," by Van Eyk, at Ghent. Moreover, it is equally evident that the subjects should be arranged in panels conforming to the eight great piers of the dome. This general arrangement is common both to Mr. Burges's iconography, and to sundry designs which preceded it, but which were not shown him.

It is neither necessary nor desirable that the design should be a copy of St. Peter's, or indeed any other dome. The designs alluded to, for instance, would not exhibit so overpoweringly the vertical lines as is done in the dome of St. Peter's, but would be rather more in accordance with the arrangement of the decoration in St. Stephen, Walbrook.

It will, I hope, be possible when the time comes for preparing the pictorial designs for this great work, to enable the artist who may be selected to qualify himself by some special training for an undertaking so much beyond the scope of the training of the present day, in which the chief rewards are offered for works of *genre* and designs of a very different stamp. It is true, there are among our first painters men who have loftier aims; yet, to ensure adequate designs for St. Paul's dome, some months spent in the contemplation of such works as those of Raphael in the Vatican; of Luca Signorelli, and Angelico da Fiesole, at Orvieto; of Luini and Gaudenzio Ferrari at Como and Varallo; and not without reference as to the *execution* of the work, to the marvels of the Sistine Chapel and the Parma frescoes—in fact, a special journey with this end in view, undertaken by the selected painter—would be found an almost necessary preparation for the task. I pass over rapidly the other parts of the walls and roofs where pictorial decoration is contemplated, because I consider that the first effort will be made with the choir apse and the dome. The dome of course implies the eight spandrils, two of which are done, but nothing as yet decided as to the remaining six. The roof of the choir, however, offers twelve pendentives, admirably suited in respect of light. There would be twelve large spaces on the sides of

the clerestory windows, besides many other spaces of smaller size, such as the spandrils of the pier arches and the triforium panels.

The nave offers about the same quantity as the choir, with the addition of a dome of sufficient diameter to be pictorially treated near the west end. The transepts, though less, still contribute their quota. There are also four apses, or semi-domes, at the intersection of the aisles with the dome. Consequently, there is abundance of space for the laying out of a great deal of money, which however London could well afford, and I have no doubt will afford, if the great dome turns out successfully; and, as I before said, the Committee, with comparatively very little more encouragement, would be able to grapple with this great work.

The windows form so important a part of the decoration, that it is necessary for me to say something about them. Dean Milman's Committee, when first called upon to consider this subject, associated with themselves a man whose name is well known here, the late Charles Winston, who, until his immature death in 1864, devoted unremitting attention to our windows, and this he did with the utmost abnegation of what might have been expected to have been his own feelings on the subject. It is well known that he was the discoverer of the truer material for glass-painting, and the beautiful texture and colours now imparted to the pot metal by Chance or by Powell dates from his investigations, and of the friends he had associated with himself in those researches. Yet, because he felt that at the time we are considering (thirteen years ago) there was no probability of sufficiently accurate art workmanship (which was of course absolutely necessary for St. Paul's) being obtained from any other quarter than the Royal works at Munich, and in consequence of the success of the painted windows supplied to St. Mungo's Cathedral, Glasgow, from the Munich establishment in respect of composition and drawing, though not of texture, he waived all his private predilections on this head, and strongly advocated recourse being had to Herr Ainmiller, feeling that any other course would be too uncertain an experiment. Others concurred with him in this who were most competent to form an opinion.

I believe that there was then no other safe course open to the Committee. Although I do not think the Munich windows have proved all we expected of them, yet they are very beautiful works, and gain by acquaintance. But since that time I am glad to be able to state my full conviction that English glass-painting has very greatly improved, not a little I believe from the stimulus given by these St. Paul's windows, and that the present Committee will do wisely in limiting the Munich glass to the three remaining windows which are wanted to complete the apse; and further, I quite expect that the English windows will surpass the Munich, a result which no one would have hailed with greater satisfaction (or with so much reason to feel it) than Charles Winston. The glass which has been kept in view as the model which should be aimed at is that which was executed during the twenty or thirty years nearest to 1520, and mainly the Belgian glass, of which there are fine specimens at Liege, at Hoogstraeten and the glass once at Herekenrode, and now at Lichfield, but which culminated in the Sacrament Chapel at St. Gudule, Brussels, of which the designs were made by pupils of Raphael. But there are also noble specimens in France, most eminently at Pont Audemer, at Conche, and (I hope still undestroyed) in some of the churches of Paris.

The style of these windows has been aimed at in those already executed in St. Paul's with success, I think, but a success which is capable of being pushed further, and they must still be aimed at in the great windows of the transepts and a few other places. But the ordinary side windows, whether of the aisles or of the clerestory, although they may contain some rich colour, must have more clear glass, as nothing could successfully compete with the clear sunbeams, which are wanted to lighten up the church, and the more colour is added to the walls and roofs the more reason for not entirely filling the windows with colour. Rich glass, however, at the ends of the building, so far from dark-

ening the church, will actually enable it to be better seen, as harsh unabated lights coming in at the ends are unfavourable to the general effect.

In conclusion, I feel deeply how very imperfect this sketch has been. It would require to be many times fuller, and all much better said, fitly to exhaust the subject, and I have no doubt that the rest of our time will be much better spent in the discussion which so important an undertaking cannot fail to elicit.

It may be interesting to many here present to learn that the first sign of movement, though a small one, has actually taken place in the work of the present Committee, and that this sign is made in putting up again in as conspicuous a place as before, the columns of the old screen and their entablature bearing the motto commemorative of Sir Christopher Wren :—

"LECTOR SI MONUMENTUM REQUIRIS CIRCUMSPICE."

The PRESIDENT.—There is no doubt we are deeply indebted to Mr. Penrose for this paper, in which there has been put before us more clearly than I have ever heard before the motives and objects of this great restoration. It is evidently a subject to which the author of the paper has devoted a great deal of thought ; it is also evidently one of deep interest to him, as I am sure it is to the profession generally, and indeed I may say to the whole people of England. I am happy to see many gentlemen present who are capable of giving valuable opinions on this subject, and with his permission I will call upon the Dean of St. Paul's to commence the discussion.

After a few remarks from the DEAN OF ST. PAUL'S,

Mr. BERESFORD HOPE, M.P., past President (responding to the President's invitation), said,—I assure you, Sir, I listened to our friend Mr. Penrose's paper with peculiar pleasure, observing, as I did, how carefully, how minutely, how scrupulously, in every detail of his paper he followed from point to point the difficulties to be met, the problems to be solved, and the considerations which have actuated those who have, in concert with himself, been working at the restoration of St. Paul's for many years. I have had the honour of serving on both Committees. My dear and valued friend the late Dean did me the honour to invite me to his Committee ; my equally respected and honoured friend the present Dean has continued me in the one over which he presides. When the work was first taken in hand, our friend Mr. Penrose was not directly charged with it. At that time Mr. Cockerell was Surveyor of St. Paul's, and on the Committee he was actively aided by the ever-ready and manly genius of Sir Charles Barry. Those were the two inspiring architectural minds that helped us at first. Time went on. The drop scene fell, and rose again. New faces, new persons came upon the stage, but the same old determined intentions still prevailed, and in Mr. Penrose we see now, and in him we welcome the successor of Wren and of Cockerell, carrying out his designs with so much ability, with so much self-sacrificing determination, the great work in hand.

I will not travel over the narrative which he has given us with so much clearness and felicity of language; but I would point out that in dealing with St. Paul's we have not merely to carry out a great work of art, not merely to decorate a hall, but we have to deal with a place of worship. We have to consider a church and more than a church—we have to consider a cathedral—we have to consider the one greatest church, the one greatest cathedral, that has not been bequeathed to us from the Middle Ages, and converted from the rites of the unreformed to those of the rites of the reformed Church of England, but which has been built for that reformed Church, and for that simply and only. In that respect, therefore, the responsibility was great. If we sacrificed the use for the art, or the art to the use, we should have grievously failed in our duty. Happily, the more the work went on, the more we realised to ourselves that the two objects were not only compatible, but that the one helped and

assisted the other. We all of us recollect the state of St. Paul's Cathedral as it was before the change was taken in hand. We recollect that solemn old screen—its light and shade; the grave simplicity and arrangement of the choir. That screen was cleared away some years ago. I do not say whether the predominance of arguments one way or the other ought or ought not to have led to that screen being cleared away. All I say is, it was not cleared away without regrets; but it is gone, and its removal procured the use of the cathedral for the so-called "special services," though I myself repudiate the term, because I consider no service special in contrast to the due order of the divine worship; but, in short, it procured the use of the cathedral at those hours of the day when there happen to be larger congregations than at others—congregations which could not worship through the solid medium of the original screen, magnificent as it was in itself as a specimen of Italian art, and venerable in the witness which it gave to traditionary forms of worship.

The new Committee undertook active operations last autumn. Among the foremost questions was that of decoration, on which Mr. Penrose has spoken so lucidly; but we felt that if we took up that first we might risk the more utilitarian part of the work of the church—the maintenance of divine worship: therefore we determined to commence with the re-arrangement of the internal fittings of the church. It was a question of the choral services. A Sub-committee considered the position of the organ. The opinion of that Sub-committee, with which the general Committee cordially agreed, was that Wren's choir might be preserved, with this difference—that the old screen could not be restored, that the great new organ in the south transept must be got rid of, and that Wren's old organ, which used to face east and west, with finely composed parts in carved wood, might be readapted, both as an instrument and in its architectural form, and both the two faces renewed. The plan was that, instead of its standing athwart the church and facing east and west, it should be divided into two portions, which should be respectively applied to the large blank bays at the west of the choir, between the dome and the first arch, which were then occupied by the monuments of Wellington and Collingwood. Its musical powers, we were told, would not be affected, and the ancient faces would be as appropriate in masking the north and south organ as they were once the old screen. Under the organ, fresh stalls for the dignitaries in lieu of the old returns will be placed, designed in accordance with Wren's type, while that essential feature of every cathedral—the high choir screen—can and is to be put up just eastward of the dome. By these arrangements, the same organ and the same stalls will be equally applicable to the services at the hours when smaller congregations assemble eastward of the screen, and to those other services when fuller congregations are compelled to take their places west of that screen. Mr. Penrose referred to a letter written by Mr. Street to a member of our Committee, and laid before us, in which he suggested an arrangement by which the altar and baldachin should be erected for the special services under the dome, and that the original choir of Wren, with the old high screen, should be restored and reserved for other occasions. Any suggestion from such an authority was of course received with the greatest respect; we printed it and took it into consideration. But, after all, we felt that it would be more consonant with the idea of a cathedral, and with that unity of worship which we wished to carry out, that St. Paul's should not be, as it were, divided into two churches, and that we should not have to deal with two sets of services as two different things; but that we should in preference carry out the arrangement which I have attempted to describe, namely, that of Wren's choir, with the substitution of the open for the solid screen, and the extension of the choir a little to the west, so securing the same altar, the same stalls, and the other fittings as equally available alike for the smaller congregations and the crowded services on the Sunday evenings, or as I trust it may be hereafter on Sunday and on Holy-day mornings. It seems to me, with great respect for the opinions of Mr. Street, that there is a higher idea of a cathedral than the one which he has so eloquently developed—namely, the idea of its use as one

whole church, with nave and choir serving alike for the same services. This idea is carried out in every small church which has been rightly arranged; why not therefore in the great mother cathedral? Full of these views, we regarded the opposite arrangement proposed by Mr. Street to be a strong objection to his plan.

I have been so far diffuse in order to make clear to you why we have apparently done so little practical work within the walls of St. Paul's, and why Mr. Burges' admirable Report, which has laid on the table for several weeks, has not been taken up. It is because we felt that until we had settled duly and deliberately, and so as not to lead to afterthought, the whereabouts of the stalls and the whereabouts of the organ, on which the great worship question depended, that it would be playing with our opportunities to plunge into the many and minute details of the iconography of the church. Then, as to the question of the painted glass for the six windows of the apse, three of which have been already executed at Munich from the designs of Professor Schnorr, and the remainder partially designed by him, we were in a manner pledged. Criticism, however just, has been exhausted; we must own that the Munich school of glass is a great one, and we cannot forget the eminence of the artist who was engaged to make the designs for these windows. Two have been some time completed, and the third was opened on Ascension Day. So it was felt by the Committee a debt of obligation on us to complete those six windows out of the resources which have come to hand. They are being completed now, and when they are finished you will have one connected work in the painted glass of the east end of the church, which will probably give the key to the future decoration of that portion of the cathedral. As to the painted glass of the remaining windows, nothing will prevent us from availing ourselves of these artistic resources of which I am glad to recognise so ample a store in England. It is probable that by the end of this year those windows will be completed, as also the organ and the screen, and then to that extent the great object we have had in view—that the decoration of the structure and the realisation of the great purposes to which a cathedral should be devoted, will have gone hand in hand. In perfecting this double purpose, it is our wish to make St. Paul's the great exemplar. I now beg to second the motion, which, although I did not hear it expressed, I am sure it was the intention of the Dean to have proposed, namely a vote of thanks to Mr. Penrose for his very able paper.

Mr. G. E. STREET, A.R.A., Fellow.—I can assure you, although my practice as an architect has been in a totally different style to that to which the architect of St. Paul's devoted himself, I nevertheless have always looked upon this structure as the work of a real artist; and I feel it must be accepted with all its defects, if defects they can be considered; that it should consequently be preserved as nearly as possible as its great architect left it, and that it should not be altered to suit what happens to be the fashion of the present day. Mr. Penrose and Mr. Beresford Hope have already referred to me as having taken formal exception to the scheme of the Committee, and I will state in a few words how and why I did so. Having expressed somewhat strong views on this subject to a member of the Executive Committee, my friend Mr. Richmond, he asked me to put my views on paper. I at once did so, and when Mr. Richmond laid them before the Committee, they did me the honour to print my letter. I believe, however, only a few copies were privately distributed, so that what I have said has not been made known to the public at large; and I am glad that I am enabled this evening to explain my views. The letter is too large for me to read to you, but I will say a few words in explanation and defence of the ideas I have suggested in opposition to those which Mr. Penrose has laid before you on behalf of the Committee. In the first place you will observe that on reading the *Parentalia*, the supposed intention of Wren with regard to the decoration of St. Paul's is founded, as Mr. Penrose indeed says, upon excessively short and slight suggestions on his part. I take it that all Wren's sug-

gestions in the way of decoration only amount to this—that there should be some sort of mosaic in the dome, a marble baldachin over the altar, and such colouring of the vaultings as might be required. It is pretty clear that his conception of colouring did not apply to the walls, which he had built of stone, but rather to such parts as were plastered. Mr. Penrose, quoting Sir C. Wren, describes the dome as being richly painted by Thornhill, and it is in evidence before us as a specimen of what was then considered rich painting; but it could not be considered possible or desirable by any one to continue such paintings as these throughout the church now, in spite of Sir Christopher's approval of them; and if the scheme is carried out as suggested, both in the Report of the Committee and in Mr. Penrose's paper, we should have a scheme of decoration totally different in colour and design from that.

But, beyond this, I observe in the Report of the Committee put upon the table just now, it it stated with regard to the marbles they propose to use, that "whether used structurally, as replacing the stonework of the principal pilasters, or in panels and inlaid patterns in the walls and pavement, they would all be arranged so as to impart a fuller idea of sumptuousness." The Committee start by substituting for Wren's plain stone work, marbles for the pilasters and panels; and I appeal to you whether this must not be regarded, not as a completion or restoration of Wren's work, but as an entirely new work which must alter the whole character of the fabric, and modify or change all its architectural lines and features. Then, again, Mr. Penrose says he advocates as much mosaic as he can have, and has made this subject one of special study. He says, and I agree with him so far, that 50 feet from the eye should be the nearest point at which any of it should be placed; but nearer than that he proposes to introduce sculpture and coloured marbles; whilst finally, in obedience to what is pretended to be Wren's cherished wish, it is suggested that Thornhill's pictures on the dome, which, according to him, Wren had seen and approved, should be replaced by new mosaics. That seems to me, as I hope it will to you, somewhat too large and rash a programme for the conservative treatment of a great church. For my own part, I must say that I cannot understand upon what principle we are to treat St. Paul's in any other way than we would the work of any of the architects of our old English cathedral churches, or why Wren's work, if worth keeping at all, is to be treated with so little real respect.

I will now, with the permission of the meeting, read one or two short extracts from my letter to Mr. Richmond, which bear specially on this point:—

"Now is it possible to do very much in the way of applied decoration to the walls of St. Paul's "without, at the same time, wholly altering the architectural character of the interior? If we are to "succeed in such a work, it must be by putting only such decorations on the walls as would have "been applied under Wren's own direction. Does any one person believe either that such a course is "possible, or that if attempted it would be pleasant in its result to one single human being possessed "of any artistic feeling? It is true that Sir Christopher Wren had some idea of introducing "mosaic decoration. If his mosaics were to be at all like all others of the same period we may "perhaps be grateful that he never carried his idea into execution! But the idea seems to me to "have been a very vague one, so far as I can make out, and, at the outside, must have been conceived "with reference to certain portions of the wall which he had not finished with wrought stonework. "I cannot and do not believe that he ever conceived, for instance, of such treatment of mosaics as we "see in those lately fixed below the dome; still less do I believe that he had conceived anything in "the style of the earlier kind of mosaics, which are in every way so much more true in principle and "beautiful in effect than are those of later schools, which Mr. Watts and Mr. Stevens have followed "in their work. In short, the more one attempts to picture to one's self what Sir Christopher Wren "*did* intend to do in the way of decoration of his walls, the more does one find one's self at sea, and "unable to find any firm footing whatever! . . . . In speaking in this decided fashion, I am perfectly

"consistent. I should say exactly the same, were some one to propose, for instance, to take our "great William of Wykeham's work, at Winchester, in hand, and to bring it up to our latest standard "of what is correct by covering the noble but colourless mouldings, panels, and carvings of his work "with colour or mosaics. I should feel such a proposition to be essentially sacrilegious, and should "protest against it with all my might. I should do the same for any of our great mediæval monu- "ments. And yet in their case I should know very well that to some extent at least, if not to a "very large extent, *they* were originally decorated with colour. Is no one proud enough of Sir "Christopher's work, to feel for him as I do for Wykeham? Are all those who are interested in "St. Paul's really ashamed of the naked proportions of the work? Can they see no beauty, no "dignity, no magnificence in its interior? If they cannot, then, Goth as I am, I think I really "appreciate the church more highly than they do. I have looked long and carefully at the interior, "till I have learnt at least to respect the intention of its architect, and in some degree to be impressed "by his achievements. There are, no doubt, many features which one would wish otherwise. But it "is impossible to sit long under that aweful dome without feeling that the building has a merit and "magnificence wholly its own, and of which we should be careful how we rob it. Were the church "one of my favourite Gothic cathedrals, the treatment I should advise would be very simple, and "would, I believe, command general consent. It would be that we should first of all restore it to the "state in which it was left by its architect, by cleaning it of dirt and whitewash. It is, to say the "least, a very damaging suggestion which the friends of St. Paul's make, if they say that such pious "care will not suit its particular case, and I do not agree with them in holding such an opinion. I "believe that the mere restoration of the stonework to sight would in itself be a great and perfectly "proper step to take. There has been some talk, I believe, of encrusting its walls with marbles, of "substituting granite piers and bases for stone, and of other similar constructional alterations of "colour. On this point I venture to say that any practised architect would tell you at once that you "might easily alter the whole architectural character of the building by any such alteration. Poly- "chromatic construction is an art of the greatest value and interest; but it cannot be adopted or not "in a building as opportunity may offer. It must be adopted from the first, and with deliberate "intention and care. It can never be successfully introduced afterwards; and it is amazing to think "that it should ever have been proposed at St. Paul's."

Having thus stated my views about decoration, I may as well correct a little mistake of Mr. Penrose's, who thinks that I repudiated all decoration. I did, however, suggest some decoration in mosaic, and probably enough, if my other suggestions were adopted, for the funds. There are parts of the cupolas which are not of stone, and which I for one would be glad to see delicately painted or decorated with mosaic. The reason I asked for an entire reconsideration of the case in urgent terms was that it appeared to me that in this magnificent scheme of decoration the Committee were losing sight not only of the respect due to Sir C. Wren, but just as much of what Mr. Beresford Hope says should be the first object they should have under consideration—viz., the promotion of the best and largest use of the church. I am sure he will agree with me that we do not want St. Paul's to be restored merely to be used, as it has been for the first fifty years of this century. We want the use of it, which has been inaugurated during the last few years, perpetuated in its arrangements in a more religious way than is now the case, or is purposed by the Committee. To those persons who are not favoured with reserved seats at the services in St. Paul's, but who sit down where they can, there can be only one feeling of regret, that such great efforts should have been made in the way of services for the people with such small results as far as the impression of the service upon the people goes. I do not see how, according to the scheme proposed, that is to be in the slightest degree amended. The altar will be an enormous distance from the people

seated under the dome; the choir will be at a great distance, whilst nobody in the transept will be able to see who is in it. I suppose no more remarkable instance even of a Committee's views of restoration was ever given than that which was mentioned by Mr. Beresford Hope to-night when speaking about the choir arrangements, which seem just to have been decided on—viz., the proposition with reference to the organ, which was erected by Wren so as to nearly fill the arch opening into the choir. The Committee having tried other schemes, have now, it seems, resolved to cut the organ in two, and place one half on one side of the arch and the other on the other side. It is quite evident if this be really done, you will have your "box of whistles" in a position that Wren never dreamt of, and this in spite of the fact that Wren himself planned the organ, and the screen on which it stood, before this completion of his work began. Of course one might have expected to be met, if one had proposed such a course, with the remark—"What a barbarous thing it would be to take away the organ which was designed by the architect himself." And yet they have not only done this, but have taken away what has been properly called by Mr. Hope his "magnificent" screen; but that has disappeared altogether, with its old inscription to the architect, and is now, as Mr. Penrose informs us, to be erected as a screen to the north door, a use for it which I can neither understand nor approve. Having said so much, it would be fair enough that I should be asked how I would use the church. "You approve," it may be said, "of the using of the body of the church and restoring the screen; but how are you to combine the two with the use of the existing choir arranged by Wren himself?" It seems to me, then, that the obviously best mode of doing this would be by putting a second altar under the dome in front, that is, to the west of the old screen, and restoring this old screen to its old place between dome and choir. You might have a magnificent baldachin, with an arrangement for the choir something in the fashion of that of Florence Cathedral. Then both altar and choir would be visible from the whole of both transepts and nave, and though you would take away some of the space under the dome, you would nevertheless have a far larger space for really intelligent congregational worship than you can get in any other way. I would ask members of the Committee to go down week after week into the body of the church, and see whether they can hear the service or join in it. If they joined in the singing of a chant, they would, I am sure, somewhat astonish their neighbours with their skill; but if the choir were in the middle of the people it might be practicable for every one with ordinary knowledge to join; and as to the statement which has been made, that if the organ were restored to its old place it would be impossible to use it for the nave services, that is an entire mistake; for it might very well be played from the end where the organist would see both nave and choir; and if the old organ is not large enough, it would be easy to supplement it by additional portions placed under the first arches of the choir on either side, where they would not be an obstruction to the view of anything.

It is a somewhat remarkable circumstance that the views as to the arrangement of the church which I suggested in my letter to Mr. Richmond two or three months ago, were, as I understand, suggested about the same time in an article by Messrs. Somers, Clarke, and Micklethwaite in the "Sacristy." I have not seen that article, but I am told it takes the same view that I do; whilst I find in a letter from Mr. Fergusson, in "Notes and Queries," that this same scheme has been proposed to the Committee by several eminent architects. Thus, we have a number of men, without any knowledge of each other's proceedings, proposing the same sort of scheme, the practical result of which is that you should preserve Wren's own arrangements of the choir intact for the services when there is not a large congregation, and that you should make the most beneficial use of the vast unused body of the church—dome, transepts, and nave—by putting a second altar under the dome in the midst of the people. I do not like to detain you longer upon a statement made in this way on a question on which I ought to have been prepared to make a rather more formal statement, rather than run

risk of damaging a good cause by such very imperfect remarks as I have addressed to you to-night; but the more I hear of the details of this scheme, the less am I satisfied with it, because one thing after another is mentioned as being about to be done, and none of them are of the happiest description. To take one instance only: with respect to the proposed decoration, we were told this evening that among examples of the sort of paintings that would be suitable for adoption in St. Paul's were the fresco paintings by Correggio in the Cathedral at Parma. [Mr. PENROSE.—With a view to distant effect?] That is precisely what is understood, and I was about to say that, however beautiful the paintings at Parma are—and that they are very beautiful in some respects any one who knows Toschi's engravings of them will admit. At the same time, anything more ruinous to the whole general effect of the colour of a building than they are I cannot conceive, and I am surprised that they should be quoted as being in the least degree models for us. [Mr. PENROSE.—I agree with you there.] In conclusion, much as I differ from the scheme which has been laid before us, and earnestly hoping as I do that it will be modified largely before it is put into execution, I can honestly say that I have only one wish in the matter, namely, that the honour and reputation of Sir C. Wren should be most jealously cared for, and that his great church should be fitted for use in the best possible way, and there I trust will be the actual results of the criticism which I have ventured to make, and of the discussion which they may promote.

Mr. T. GAMBIER PARRY, Hon. Member.—Being a member of your Institute, and called upon by the President, it is impossible for me to refuse to say a few words. I cannot go altogether with Mr. Street in all his ideas. He would, I am sure, agree that his most cordial admirer should be a man whose opinions should be free, and who would discuss his views; and he will forgive me if I have my own ideas. I think, in accordance with what Mr. Street says, our first duty at St. Paul's would be to clean the building; the next would be to render it as appropriate a place as possible for Christian worship. I agree with that; but there is another fact beyond these two, and that is one but little touched upon. Everybody has fought shy of it. Mr. Penrose has given a general sketch, but he has fought shy of the details of the artistic treatment. We have three difficulties before us. The first is founded upon what scheme we should adopt; the second is what artist we should employ; and the third is what censorial authority should be assumed and exercised over his designs. Of the first I will say very little, because it has been treated in a very able manner by Mr. Burges in his elaborate Report; of the last I will say nothing, because this is not the time to discuss it. About the second we certainly have a difficulty. It is very certain that nothing can be possibly worse in decoration than badly-used colour. Mr. Street does not repudiate the use of colour altogether; but I confess that the difficulty we must experience in choosing an artist for such a great work as this will be very great indeed. The difficulty is, that our artists have been occupied with a different class of works; still, when we look at what has been done, whether in politics or in art, the occasion has commonly brought forward the man. I do not know why, under the circumstances, an idea or an inspiration might not be vouchsafed to a man who has passed his time in the ordinary way of modern artist life, and who might prove to be very capable of realising our purposes; and although I do not know many at present, who have studied religious art on a large scale, I do not look forward with despair to the discovery of competent men. Our motto in dealing with St. Paul's should be "Festina lente." I think, if we were wanting in courage in this matter, we should be unworthy of ourselves. We must not stop after having wiped off the whitewash. I believe that we have amongst us persons capable of forming an exalted idea of what the interior of this edifice should be. I believe that Wren himself may have conceived in his mind things infinitely more magnificent than Thornhill's pictures. It is certain that all works in colour require to be supported by colour elsewhere. Painted windows are blots, unless supported by painted

walls. But then comes the difficulty of what the paintings should be, and of what the whole of that great interior should represent. If we begin at a central point, I think we should make a mistake. I will tell you why. Because I conceive a central part like the cupola is one that we must approach gradually. We may have an idea of what it should be, and what it should not be; such as that it should not be covered with one unbroken subject, such as a "Paradiso," or any other which would cover the whole ground. Any such composition would destroy all sense of construction, and reduce the dome to a thing of air. But I conceive that, however great ideas may be, we require time to digest so vast an undertaking as that of the cupola of St. Paul's. I know it is said, "Do that, and you will get the money for the rest." But such a work needs long preparation, and the rest should not be delayed for it. I think the first duty is to make the building glorious where a church ought to be: viz. about the altar, whether the altar be in one place or another. First complete the church round the east end, where the altar is now; it will be then time enough to consider the necessity of another. I think designs in fresco and in painting about the east end should be executed, and from them we should be able to see better with regard to the cupola, and in such a course I think that we should have begun where Wren would have begun. It is a good thing that the scheme proposed by Baron Triqueti has been thrown aside. The three large figures designed by Mr. Leighton and Mr. Watts, good as they were, have also been disposed of for the same reason: viz. that they would have ruined the scale of the building. With regard to mosaics, the east end and ceiling of the choir would be the places for the commencement of mosaic. With regard to colour, I would say this—that we should want, of necessity, the use of paint. I think we are bound to use a certain amount of colour; without it we should be unable to give warmth and life to the deep hollows of panels and cornices, where, if paint were used (of a proper material which would bear to be washed), you would have all you would require for that support of mosaic which I believe its powerful colours would require.

With regard to Wren's idea of the arrangement of the church we have heard some admirable suggestions from Mr. Hope and Mr. Street on that subject. No doubt Wren himself had no idea of an altar any where but where it is. For my own part I should be glad to see churches arranged on Mr. Street's plan, where there could be an altar for large congregations and others for small ones; and it would be a good thing if it were possible that St. Paul's should be so arranged. But we have to deal with things as they are. We have to meet the requirements of the present necessities in St. Paul's, and we may do so without obstructing future developments. I think we may be able to re-arrange the organ for the greater service in the nave, and for the smaller service in the choir, so as to follow out Wren's arrangement. That Wren ever conceived a great building with a huge, awkward fortification of wood and organ pipes in the middle, so that all the effects of architecture were marred by a block beyond which your eye could travel no farther, I do not for a moment believe. The idea of Christian worship is, that it should be held in a church aided by the sight and the hearing of the organ itself. I cannot conceive that Wren's idea was to keep the people at the back of the organ screen. The modern requirements of great congregations were then unknown. The scheme for spreading out the organ, so as to make it available for all the services is, I think, one which may be carried out with good effect. As one of the Committee, and as an amateur who can put his foot into a thing and draw it out again easier than a professional man, I have offered these rambling remarks. I came into the room without a word or a thought prepared for expression. I came here to be instructed; and I almost wish I had been called upon, if at all, later, when I should have heard the opinions of those who are far more competent than I am myself to speak upon the subject.

The DEAN of ST. PAUL'S.—I wish to say a few words—not as part of the discussion, but simply as

an explanation—relative to a matter which has come under my cognizance as Dean, and not under that of the Committee. It is simply with reference to some remarks from Mr. Street by way of explanation. He spoke, and truly, of the very great inconvenience of the arrangements for the present Sunday evening services. That has long been under the consideration of the Dean and Chapter, and if that inconvenience remains, I say "our poverty and not our will consents." I hope, under an arrangement contemplated by the Dean and Chapter, but not under the Committee—and they do not appear in their Report—much of the inconvenience will hereafter be obviated. With regard to the impossibility, under present circumstances, of satisfactorily hearing the services, I can say that the organ, as we propose to place it, will in these dome services be nearer to the greater part of the congregation than if it was placed where the screen stood some years ago. Allusion has been made to the Report of Mr. Christian, in which he recommends that the first thing done should be the cleaning of the walls. I believe I may say that Mr. Christian's Report coincides with a suggestion I made to the Ecclesiastical Commissioners, which has been considered further by coincidence, or in consequence, in Mr. Christian's able Report. The only reason why that point of cleaning was not mentioned in the Report of the Committee was that it was considered to belong to another department. The Committee undertook the decorative part, while the Dean and Chapter retained to themselves, on the supposition that they would get the means of doing it, the duty of clearing off the dirt which has accumulated for many years, and also the duty of adapting the Cathedral more efficiently for the purposes of Divine service. The reason it is not mentioned in the Report is that it is under the consideration of a different body.

Mr. G. E. Street.—Mr. Gambier Parry has misunderstood me if he supposes I only wanted to clean the Church. On the contrary, I made a suggestion for spending money upon the choir under the dome; and I said, as the Committee thought it right to consult Mr. Burges on the subject of decoration instead of spreading lime all over the Church, they should request him to design the most beautiful baldachin he could, and then we should be certain to have a work that we might be proud of.

Mr. E. Poynter, A.R.A., said: I have had as yet not much to do with the decoration of public buildings. My experience is mostly confined to the mosaics in the central lobby of the Houses of Parliament. I need hardly say I have not considered the decoration of St. Paul's as a whole. There seems to me to be a number of large spaces which might well be filled with paintings or mosaic; and it is on this subject I wish to say a word or two, because Mr. Penrose and most of those gentlemen who have spoken have alluded to mosaic as the means to be employed for the coloured decorations. The use of mosaic seems to me open to certain objections. It is impossible in the present day to return to the archaic form of mosaic decoration used in St. Mark's at Venice in the middle ages, when a very simple cartoon was enough to guide the mosaicist in carrying out the work, and the process was comparatively a cheap one. The mosaic work of the present day is on a different footing. To have a mosaic properly executed now it is necessary for the designer to make a highly finished painting, and the work of the mosaicist is confined to making a fac-simile copy of it. Thus the work has to be done twice over, and double trouble and expense have to be incurred in producing it. If the funds admit of it, it is the better form of decoration, because it is so absolutely permanent; but a great deal of money must necessarily be spent on this double process. I think, unless a sufficient sum can be obtained for the employment of this material, it would be better to resort to the old method of fresco-painting, or something of a similar kind. The First Commissioner of Works has lately called together a Committee of the artists employed in the decoration of Westminster Palace to consider the question of fresco painting, and a chemist has been employed to enquire into the cause of the deterioration of modern frescos. I have never painted in fresco myself, so that I cannot speak from any experience of my own, but the chemist I have mentioned has been able to point out with clearness and in detail the cause of

every defect that has been discovered in the fresco paintings of the Houses of Parliament and elsewhere, and he has found out in every case what the cause of the deterioration has been, and he says with much truth that, as in every fresco he has examined in this country, some parts are as sound as the day they were painted (in some even the whole is perfect with the exception of a few square inches : it cannot be from the effects of the climate that the frescos are destroyed. If one part can be made permanent another can. I do not dwell in detail on Mr. Wright's paper, as it will shortly be published in a report from the Committee to the First Commissioner of Works. I mention it merely as a hint to the Committee for the decoration of St. Paul's, that something besides mosaic might be used in the coloured decorations of the Cathedral. If the causes of deterioration in fresco are well known there is no reason why the artist should not be able to avoid them ; and it must be remembered that if fresco can be made permanent, it is only next to mosaic in durability. I think, therefore, that in the case of St. Paul's, unless an enormous amount of money is to be spent, fresco would, at all events for spaces near the eye, be a better form of decoration than mosaics ; also, it is a material which, above all others, lends itself to large style of drawing, especially suitable to so noble a building as St. Paul's Cathedral. The time and trouble spent by the artist in preparing a painting for the mosaicist to work from, might just as well be employed on the wall itself, and unless a very large sum of money can be spared to have the design properly reproduced, the mosaic result will always be inferior to the original pattern.

Mr. MICKLETHWAITE.—Mr. Street has already alluded to the scheme put forward by Mr. Somers Clarke and myself. I do not intend to pass again over the ground which he has done, but to reply to several objections which have been raised to his proposal as well as to ours. First, it is said that we wish to cut the Church in two. We reply that it is already two, and we merely wish to utilise both portions, whilst the Committee are vainly endeavouring to make them one. If St. Paul's were a small Church of 150 feet long the arrangement they propose would be practicable, for then the Church might be used as a whole. But this can not be done with the present building. Certain parts of the service, the Gospel and Epistle for instance, are intended to be heard by the people. If these be read at the altar, the bulk of the people being in the dome area, the reader and his audience will be separated by some 150 feet ; and, if to avoid this he comes forward to the choir arch, he leaves at his back all those who are sitting in the choir. And again, the chancel—for it is a mere chancel to which the Committee would reduce the eastern arm of the Church—is so great that it would be practically impossible to obtain a choir large enough constantly to fill it. The fact is that at St. Paul's the choir is, always has been, and so long as the services are performed there, always must be the Church, and all the worshippers must be placed in it. If the dome area is to be used—and it is absurd that it should not—it must itself be provided with all the apparatus for public worship. We are also told that we should destroy the vista. May I ask : "What is the æsthetic value of a vista?" It is simply extension in one direction only. In a large building we require height and breadth as well as length, and to exaggerate any one of these is to detract from the other two. I can not help thinking that Ely Cathedral, for instance, would look larger if it were 100 feet shorter. Here at St. Paul's the whole building culminates in the dome, and the existence or not of a vista beyond it is unimportant ; and even if it were not it will be as much destroyed by the Committee's screen and organ as it can possibly be by our altar and baldachin. It is further said that the plan proposed by Mr. Somers Clarke and myself is a greater departure from the intentions of Wren than that of the Committee. So far from this being the case we proposed to replace much that the Committee have already removed. The removal of the stalls 10 or 12 years ago destroyed Wren's choir as completely, though fortunately not as irrevocably, as if they had been chopped up into firewood. It seems to be forgotten that Wren not only designed those stalls, but designed them to fit their places, and that they are not so much furniture to be moved here

and there at pleasure. It is now, I understand, proposed to alter them still further from their original condition; we, on the contrary, would replace them. For the removal of the organ the Committee plead Wren's stated objection to placing it on the screen. I think, however, that it was not so much to the position as to the size of the organ that Wren objected. He had designed a case of a certain size and he protested against being compelled to increase it. In conclusion, I should like to ask what advantage the Committee's proposed new arrangement has over the existing one. They seem to me to be practically alike and equally unsatisfactory. Ten years ago alterations were made which are now in turn to be superseded by others as little likely to be permanent. When is this to end? I think that the Institute, as representing the architectural profession, ought to protest against the work of a great artist being thus made the subject of mere experiment. Let Wren's work be left alone, and let any alterations be made by addition only, so that if they are not satisfactory they may be taken away and no harm done.

Mr. PENROSE (in reply upon the discussion) said: There are a few points on which I would say a word or two. Mr. Street has spoken of the use of marbles. In the apse the marbles proposed by the Committee to be introduced are simply real marbles in the place of the painted marbles, which Wern intended as a temporary decoration. Then as to the spandrils of the dome, it has been asked whether any decoration of them was intended. I think it was so intended. These spandrils are built of soft Oxfordshire stone, as though they were not intended to be parts of the unornamented structure, and if they were not painted we should have considerable difference of colour. I would refer to one observation of Mr. Micklethwaite on the question of Sir Christopher Wren's organ being placed in the position in which he wished it to be. I feel quite certain it was not so placed, and this independently of any traditional statements of the objections urged by Wren against it. There is in the Cathedral a drawing of a design for the organ in one of the arches of the choir—presumably on the north side as less obstructive of light. It is a different design from the present, and is shown above the stalls and under the arch, just as the organ stands now. Also, when Wren found it necessary to place the organ in the centre, he had to interpolate incongruous supports of stone under the vaults in a way which any architect would see at once to be unconformable to the architecture of the crypt, and inserted solely to meet an emergency for which he had made no preparation. It is too late in the evening to reply upon the various other matters which have been discussed, and I conclude by thanking the meeting for the kind attention they have given to the paper, and to what I have now said.

The PRESIDENT, in formally proposing a vote of thanks to Mr. Penrose, said: In spite of conflicting opinions, it is gratifying to know that a vast amount of anxious thought is being given to this subject, not only by the Committee, but by many architects, to whom it is naturally one of great interest. No one could have heard the paper without being impressed by the earnest desire Mr. Penrose has manifested to profit by any suggestions that may be made, and to do credit to the great work on which he is engaged. We have had a most interesting and valuable evening, and I beg to propose that we tender our hearty thanks to Mr. Penrose for the paper he has given us.

The vote of thanks was unanimously passed and the meeting adjourned.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, 5th June, 1871, the following Papers were read—
EDWARD I'ANSON, Vice-President, in the Chair :—

ON THE USE OF PORTLAND CEMENT CONCRETE AS A BUILDING MATERIAL.

By THOMAS H. WONNACOTT, Associate.

THIS subject has for several years awakened a considerable amount of interest, and provoked much inquiry and discussion. This is owing partly to the novelty of the material, and partly to the statements made in its favour by some of its advocates. These statements are some of them just, and capable of clearest proof; others are not borne out by experience; and fairness and candour demand that they should be disproved, and the public and the profession put in possession of the truth concerning them.

I propose to examine some of the chief of these in the order of their importance, hereafter. Before doing so, I may be permitted, by way of preface, to say that all my remarks have reference to Portland cement concrete, built in continuous layers, in what has been called the monolithic system, with such machines or frames, as those patented by Tall, Drake, and others. Roman cement for concrete walls is out of the field, and concrete blocks are neither better nor cheaper than ordinary brickwork.

The use of lime concrete dates from very early times, and its value has never been questioned. The introduction of cement concrete as a substitute for stone and brick, with far greater pretensions to usefulness, is of very recent date, and in a diminutive way may be said to mark an era in the history of construction. Though quite of modern origin, it has already won for itself almost universal acknowledgment as a valuable building material. This, I think, is a point that needs no discussion. The points in connexion with it which do call for examination are—whether it should supersede brick and stone, and whether it is universally applicable with safety, profit, and economy. As it has been my duty to employ it frequently in works varying in cost from £100 to £4,000 or £5,000, I have had opportunities of testing its qualities, and my convictions having assumed a somewhat definite shape, I venture to express them with an approach to confidence. I have no hesitation in saying that the general impression of its value is in the main correct. By severe tests, its claim to adoption has been fully established.

But approval must not be unqualified. It has its drawbacks and defects, as well as merits, and these should in fairness be shown. Influenced by a knowledge of these, I would not advocate its universal, or even large adoption, and would deprecate its use for many purposes suggested by pamphlets I have read on this subject. It is also to a great extent incapable of artistic treatment, except at great cost for moulds, patterns, &c.; and for these reasons, and others hereafter mentioned, I am persuaded neither brick nor stone has anything to fear from competition with it. Its claims to superiority, as stated by its advocates, are chiefly the following :—First, much greater strength than brick or stonework in mortar; second, less cost; third, superior weather-proof and water-proof qualities; fourth, that it is a non-conductor of heat and sound; fifth, that it can be constructed with

safety more rapidly than work in mortar; sixth, that it requires no external facing, and only one coat of plaster internally, that chimneys require no pargetting, that bond timbers, lintels, and bressummers may be dispensed with, and that roofs, gutters, and stack pipes may be constructed wholly of this material.

These are the demands made on our credulity by those who advocate its general introduction. If proved to be just and true, they would lead to a revolution in our art, but they are not yet all established beyond controversy, and I venture to believe they never will be. Before examining these claims in detail, I may be permitted to offer some suggestions on the preparation of the concrete. The proportions that have been found to make the strongest work are six of clean gravel or ballast, broken bricks and flints; one of sand, and one of Portland cement. The sand I think adds to the ultimate though not immediate strength, by multiplying points of contact and giving a better bed for each stone of the aggregate, and is especially necessary if the gravel is large. When thus composed, it is not unlike a stone wall, built with one of sand to one of cement, in random courses. The gravel or bricks forming the aggregate should pass through a $\frac{3}{4}$-inch mesh. Smooth, non-absorbent stones, as chalk flints, are not so good as those that are somewhat porous and rough on the surface. This is accounted for by the fact that the process of "setting" in the cement is partly mechanical and partly chemical; the mechanical part of the process demanding some pores into which to penetrate, or some roughnesses to grasp. Large stones and brick bats may be advantageously used as "packing,"—that is, they may be "packed" or pressed into the mass while in a semi-fluid state, and if thoroughly surrounded by the concrete, will lessen the cost without diminishing the strength.

It may appear strange, but I have not found a larger proportion of cement than one in eight increase the strength of the concrete. On the contrary, it appears to diminish it. I was accustomed to specify for piers, arches, lintels, &c., one of cement to five of gravel or bricks, but I have abandoned the custom, finding it useless. Why the larger proportion of cement should make weaker work, I am unable to explain. For ordinary walling I have found 1 in 10 sufficiently strong. Mr. Reed, in his work on concrete, says that 20 to 1 has been used for engineering works at Copenhagen, and I was once informed by an experimenter that he had gradually lessened the proportion of cement to 1 in 24, and found it then make fairly strong work. But in such a case the conditions must have been exceptionally favourable, and the dispersion of the cement among the mass perfect. As a rule, I should fear to recommend a less proportion than 1 in 10.

Before using the cement, it is desirable to ascertain its age. It should never be used less than a month old, and if so new as this, should be exposed to the air on a dry floor for four or more days, and occasionally turned over. If this is not done, it sets too rapidly, much to the delight of the inexperienced; a delight I need hardly say considerably modified on the appearance of fire cracks and fissures a few days after.

It is absolutely essential that every cargo or load of cement should be properly tested. Work built with bad cement is no better than a mud wall. The tests usually applied are threefold. Weight, size, and tensile strength. The weight should be not less than 110 lb. per bushel. In size it should pass through a No. 50 guage sieve, leaving not more than 10 per cent. residue. Its tensile strength, after seven days setting under water, should be not less than 200 lb. per square inch. Some cements will bear twice that amount of strain. A much more simple method of ascertaining its quality is given by Mr. Reid, and one that has the advantage of giving its results in 24 hours. He says—"Make up two circular cakes of neat cement 6 inches in diameter and half an inch thick, with the smallest quantity of water. When they are sufficiently set to permit removal from the board on which they are mixed, put one of them into water and the other in the open air. After 24 hours' immersion examine

the water cake, and if there are no indications on its surface of cracks or fissures, it may be considered free from excess of lime and thoroughly hydraulic. The cake in the open air should be light grey in colour. If it looks yellow and ochrey, the cement contains too much clay, and is deficient in tensile strength. If the water cake cracks, and the air cake is of a whitish grey, the cement is worthless, and should at once be removed from the premises.

I have never known of but one case of failure in works under my supervision. This was owing to the inferior quality of the cement, and was discovered and corrected before the walls were above the ground floor line. The merchant had guaranteed the quality, but I learned that nothing should be taken on trust. Equally with bad cement, loam or clay in the gravel or sand is fatal to stability. In mixing the cement and gravel, the mass should be turned over twice dry and twice with water, which should be poured on through a perforated hose like a water pot.

I will now speak briefly of the claims of cement concrete to superiority, of which mention has been made before.

First,—That it is stronger than brick or stone-work in mortar. This is probably true of the first hundred years of the existence of each material. It is undeniably true of the first twenty years. I need scarcely say anything, I think, to prove this. I venture, however, to cite a few illustrations in support of it. We are all probably familiar with an engraving, in which a gentleman is represented as standing on a beam, a considerable height from the ground, inserted into a small pier, said in the description annexed to the engraving to be a cement concrete wall eleven days old. This picture is a sort of hieroglyphic; interpreted into English, it reads thus:—"This cement concrete wall is immensely stronger than a new brick or stone wall, and I am risking my neck to prove it."

This was no doubt considered proof positive by the gentleman who ventured, and by those who saw him. Strong arms and sledge-hammers have also been employed to drive conviction home to sceptical minds. I was once present when a quick wall was being operated on by a pickaxe, and my astonishment was great to see how little impression was made by each blow. It appeared as firm and strong as a solid block of stone. On another occasion a concrete wall 47 ft. long, 12 in. thick, 10 ft. high, was exposed to the fury of a great storm for some time in a very exposed position. It was without support, except a cross wall at one end and a small return at the other. I visited the building after the storm, and met my client and the builder there. We had all come prepared to find the wall demolished, but it was perfectly uninjured.

At another time a wall 16 ft. high, 18 ft. long, 9 inches thick, withstood on a hill the fury of a storm that blew down a 9-inch brick wall in a less exposed position. At Fernlands, near Chertsey, a house wholly constructed of concrete, it was thought desirable to cut a doorway through one of the walls shortly after it was built. The opening was dug out with a pickaxe, leaving a straight beam across the centre, 3 ft. 3 in. long, 9 inches deep and 9 inches thick. There was no hoop iron bond in this beam, but along the centre ran one of the joints between the layers, well known to be the weakest part of these walls. This beam was loaded in the centre with more than a ton; the foreman then leaped on the weight, but the jar produced no effect, and it had ultimately to be dug down with a pick-axe like the rest. The cement in the centre of this beam had but very imperfectly set at the time of its demolition. Illustrations of this nature might be multiplied, but are unnecessary.

The much greater initial energy in setting which cement has, as compared with lime, gives it this advantage, that a cement wall may be built with great rapidity, and loaded at once without danger, such a wall being as firm in seven days as a mortar one in as many months or even years.

But there are three characteristics, or qualities of cement work, which are sometimes found to diminish this strength, especially when the layers are continuous for 20, 30, or 40 feet. They are

expansion, contraction, and contortion in setting. That cement contracts slightly in setting is of course well known. This contraction is greatest in those cements that are over-limed or used too fresh. But before contraction it sometimes expands.

In examining a wall 40 feet long one day which had no hoop iron bond, and was unfettered by abutments, I observed a hair-like fissure running almost from top to bottom. I called the attention of the foreman to it, and made a mental note of it. Some days after I was again on the spot, and on looking for this vent or fissure, was astonished to find scarcely a trace of it visible. My client, who was with me, thought I must have been mistaken, but it opened again afterwards. There had been a change of weather in the interval of my visits. The barometer had, I think, fallen; possibly this might have had some influence on it.

The contraction of the cement in setting, when it is used too fresh, or when it sets too rapidly, sometimes opens most unsightly fissures, and these appear generally over doors and windows, where cohesion is weakest, by reason of the smaller section of the wall at those parts. The same thing occurs in cement facings on brick walls. At first sight they appear to be "settlements," but they are not caused by subsidences. Close examination of any concrete wall reveals small fissures, but these are not seriously damaging if the mass holds together. Knowing this tendency to fracture which is sometimes not fully developed till the facing is on the walls, I never build without the usual lintols, and would recommend a prodigal expenditure of hoop-iron bond.

In using blocks of concrete these defects are not so manifest, the process of setting being completed before they are built into the walls. Stress is often laid on the fact that cement concrete walls may be built much thinner than brick or stone. They may be, doubtless, yet I would not advise extreme thinness, for should the cohesion of the cement fail there would be less width of base, and therefore less stability. Where 18 in., 14 in. and 9 in. brickwork would ordinarily be used, 15 in., 12 in. and 8 in. cement concrete may be safely trusted. Contortion is mostly found in composite walls—that is, walls partly of brick in mortar, and partly of cement, or in brick walls coated with cement. I have it on the most reliable authority that such a wall has been twisted by a cement coating, like an elm board in seasoning.

The next point for consideration is that of cost. This is an important one. In speaking of it I shall take no notice of published estimates. Conclusions drawn from them are most unreliable, few things being more deceptive than figures framed to prove a desirable point. I have found the cost vary very considerably in different localities. In some cases it has been done for 12*s.* per cubic yard, including the cost of apparatus, but this, I feel constrained to say, was when the builder was the apparatus-maker. In others it has cost as much as 18*s.* per yard without builder's profit, or cost of apparatus. It should be remembered that the concrete and apparatus are not the whole of the cost of these walls. There are many other items which help to swell the final amount, which do not appear in the published estimates. These estimates are most of them misleading—true as far as they go, doubtless, but stopping short of what they ought to say. Added to the first cost of concrete, which is usually all that is taken into account in these estimates, I have found in nearly every case 10 per cent. of the whole cost of the building in the form of cost of apparatus. In some cases this tax has risen to 20 per cent. For hire, unless the builder has been the apparatus-maker, the charge has never been less than about $3\frac{1}{2}$ per cent. the whole cost of the building, and very rapid work is necessary to reduce it so low.

Other items appear in the form of linings, boxings, screeds, close boarded centres, chimney and flue cores, and outside cement rendering. In one house the $\frac{3}{4}$ in. and 1 in. rough boarding for screeds, &c. amounted to between 3,000 and 4,000 feet superficial. Every deviation from a flat surface, whether aperture or projection, demands a core, a box, or linings. All these items combine to raise the average

cost of concrete to about 80 per cent. of the cost of plain brickwork, and taking the whole cost of an ordinary house the saving is only from 5 to 10 per cent. It may be urged that this estimate is unfair, because it takes no notice of the fact that the same apparatus may be used for one hundred or two hundred houses; but as it rarely, if ever, happens that the same employer or builder erects so large a number of houses of precisely the same size and shape, it ought not to be taken into account in a general estimate. But if it ought, I should be slow to believe that a hundred, or even fifty houses, could be constructed with one machine. I have known an apparatus returned to the maker for considerable repairs after only once using, and another very much damaged after twice using; and the fact that one apparatus-maker offers to take back his machines, allowing only 50 per cent. of the original cost, would seem to indicate a fear in his mind that they would not last a hundred times. If men would handle them more carefully the case might be different; but we are bound to take things as they are, and not as they ought to be.

Next in importance we have to consider its damp-proof qualities. These have been much overstated also. Concrete walls are not found in practice to be weather-proof, unless rendered externally in cement, and they are not water-proof unless trowelled to a smooth surface and kept from extremes of temperatures. By water-proof I mean suitable for tanks, cisterns and reservoirs. I should certainly not advise any one to make roof gutters or rain-water pipes of this material. In these walls it is impossible to be sure that there are no cavities or interstices, especially along the bed of the layers. No amount of ramming will ensure it, or if it would the apparatus would not admit of it. An outside coating is also as necessary for basement walls in contact with the earth as for those above ground.

In passing, I may remark that I have heard complaints of the frittering away of the concrete in chimney-flues, showing it does not withstand the effects of fire. Frost has no influence on it after it has set, but during the process of setting it is affected by it as much as brickwork in mortar, the surface blistering out and scaling off. Walls should therefore be covered up, and work suspended during severe frost. It gives off its moisture very rapidly, and is generally fit for papering as soon as finished.

As a non-conductor of heat it may take precedence of brick, but I am not sure of this. As a non-conductor of sound I cannot speak in its favour, the slightest sounds being distinctly heard through its walls. I can readily believe that it is warmer in winter than brick, because of the less moisture it retains. That it can be rapidly and safely constructed is true. Leaving out of consideration the time necessary to remove and readjust the apparatus; two feet in height per diem may be safely carried up. That it takes less cement externally, and less plastering internally, is altogether contradicted by my experience. Certainly not less in any case is required, and in many cases dubbing out is found necessary before commencing the ordinary rendering, but the interstices and cavities in the concrete give a far better key to the plaster than ordinary brickwork does. Concrete offers great facilities for warming and ventilation. Heated air is readily conveyed through flues formed in the body of the walls, and admitted into the several rooms through the skirtings. The vitiated air is as readily allowed to escape through apertures in or near the ceilings.

Of the machines in use for concrete building I may not now speak particularly. They are fully described in the pamphlets, issued by the several makers. They have, however, one defect which is common to them all, and which, I think, much limits their usefulness. Every apparatus yet constructed is so rigid in its dimensions that it cannot be adapted to any increase or diminution of size; consequently walls are carried up the same thickness from basement to roof, causing a waste of materials and overloading the lower walls. By the introduction of extending plates, which permitted the lengthening of each plate 50 per cent. on the principle of Clark's shutters, I sought some time ago to remedy this defect, and so to adapt the machine as to be able to build a room of any size: for

instance, between 12 ft. by 12 and 18 ft. by 18, or between 10 ft. by 10 and 15 ft. by 15, and so on. As it is, every deviation of only an inch or two necessitates clumsy contrivances or new plates. For floors concrete may be used with advantage and economy. It also makes an admirable hearth, scarcely to be distinguished from rubbed York stone.

Pavings should not be less than 4 in. thick. On a well rammed foundation, and trowelled smooth, it makes a neat and durable floor, easily washed, and vermin proof. For terraces, landings and stairs, that are not exposed to sun, rain and frost, it also answers well. But when exposed it cracks, becomes unsightly, and is not durable—at least, I have not found it so. In arches built of cement there is no thrust so long as the material remains entire and unbroken. Seeing this it has been recommended to discard the form of the arch, and treat it as a lintel, bressummer or landing; but knowing its liability to fracture, I fear to do this, and prefer excess of caution to possible failure.

After what has been said it may be asked, Is cement concrete to be recommended at all; and if so, in what cases?

I will conclude by replying to the question, and adding to my reply a few suggestions dictated by experience, to those who desire to use it. For first, second, or even third class houses I would not recommend it, but for houses having no intricacies of plan, and no pretension to ornament, especially if bricks are dear, and still more so if the gravel can be dug on the spot or from the basement of the house, as is sometimes the case, it may be used with advantage. In thick walls this advantage is still more evident. For retaining walls, backing or filling in to ashlar stonework, for cottages, farm-buildings, fence-walls, warehouses, sea-walls, and other buildings that may be made endurable to the eye by cement rendering, I should certainly permit if I did not recommend its use. On the whole, I look on this as a material to be employed as an exception, and not as a rule. But when it is employed it is of the utmost importance that the cement be of good quality; that the gravel and sand be perfectly clean; that the cement be thoroughly distributed through the mass; that constant, careful and trustworthy supervision be exercised to secure correctness of proportions of the ingredients; that hoop-iron bond be used with no sparing hand; that wood bricks be superseded by slips not more than $1\frac{1}{2}$ in. thick, and in section like a dovetail. Wood bricks swell with the moisture of the cement, and in shrinking again become loose. Beside this, every wall should be rendered in cement externally, the usual damp course should not be dispensed with, and chimney flues should be lined with brick and pargetted in the usual manner. Given these conditions, and a wall in cement concrete may be built, in some respects as good, in others better, and in some others not very far inferior to a brick or stone wall in mortar.

I offer these remarks as the results of my own experience, to be confirmed by the experience of others, if they are correct, to be corrected if they err.

REMARKS ON CONCRETE BUILDING.

By A. W. Blomfield, M.A., Fellow.

In the few remarks which I have to make on this subject, I shall confine myself to the consideration of that system in which walls are constructed *in sitû*, by filling concrete into cases, or molds, made to shift to the various requisite heights and positions as the work proceeds. The system of building with blocks of concrete or artificial stone, cast separately and put together when dry, having little to distinguish it from the ordinary methods of construction, calls for no special notice.

Much misconception, now happily disappearing, has existed as to the pretensions of concrete building, and, in consequence, many absurd objections have been raised against it. As one instance among many, I may mention that, when a few years ago a Paper was read on the subject at a meeting of the Architectural Association, an architect gravely objected that, though much had been said about concrete *walls*, nothing had been said about *roofs*. He considered that a building was useless without a roof, and he wanted to know how it was proposed to roof a concrete building. There seemed, in fact, to be an idea that the advocates of concrete looked upon it as a new invention destined to supersede all other methods of construction. Any one who has taken the smallest trouble to investigate the subject is, of course, aware that like many other so-called inventions it is merely the revival of a very old expedient, though some of the features of the machinery now generally employed are certainly new and very ingenious and useful. The authors of other Papers will, no doubt, enter more minutely, and with more scientific details than I can, into the question of the materials and proportions proper for concrete building; I shall, therefore, say little on this point. For the same reason, coupled with a desire to be brief, I forbear to mention the numerous tests to which the material has been subjected, and the proofs of extraordinary strength and durability which have been the result. One significant fact, however, should be noticed. In using ordinary materials, no sooner is a building completed than decay commences at once, in a greater or less degree. Portland cement concrete, on the other hand, has been proved to continue to harden for a very considerable time—some say even as long as two years. As far as I can ascertain, the only cementing material to be relied on is Portland cement of the best quality, and for the other ingredients, any may be used that are usually employed in carefully composed concrete for ordinary purposes, especial care being taken that they be quite clean and free from clay or earthy particles. The proportions vary from one of cement, and eight, nine, or even ten of other material for walling to one of cement, and five or four of other material for lintels, steps, and flats, or landings. The interior of walls of more than four inches in thickness may be packed with rough stone, broken bricks, chalk, or any other similar material that can be easily procured in the neighbourhood.

Time will not allow me to enter into any description of the different sorts of cases and machinery now in use, and the various details, manipulation and use of the material; but so much has been said and written on the subject, and the system has now become so common, that anything of the sort would probably be unnecessary.

The chief advantages of concrete building may be summed up in a few words: First, cheapness; Secondly, strength and durability; Thirdly, rapidity of construction; Fourthly, economy of space.

The chief drawbacks appear to be: First, its liability to failure, from the use of improper materials, or from the want of knowledge and proper care, or from the wilful misuse of good materials.

Secondly, the limits which the material and method of construction impose on architectural design and decoration.

The question of cheapness depends on locality. As a rule it will be found that where bricks are the local material, concrete will be, bulk for bulk, cheaper; and, as it may be used thinner than brick, with equal strength, and without the employment of skilled labour (except that of a foreman), the saving is usually considerable over brickwork. On the other hand, where a local stone may be obtained very cheaply, concrete will not be found to effect any saving in ordinary walling.

In respect of strength and durability, my experience has led me to put the greatest possible faith in carefully compounded Portland cement concrete. I do not think that its capabilities in the way of fire-proof flooring, without any adventitious aid of iron girders or other supports over considerable areas, has ever yet been properly tested. Its extraordinary strength when employed for walls must now be fully recognized by all who have given it a trial.

With regard to the next point, *rapidity of construction*, although no doubt many concrete buildings have been run up in an incredibly short space of time, I think that too much stress has been laid on this as an advantage, and I believe that some disasters which have occurred are attributable (in part at least) to under haste. I have myself seen partial failures from this cause, which, by the subsequent hardening of the concrete, have stopped and gone no further.

Economy of space is only gained by the possibility of making walls (particularly internal division walls) thinner than in ordinary brickwork. Though this seems a small matter, it will be found that in a large establishment, with many small divisions, the saving in space covered is considerable. I now come to *the drawbacks*. Of these, the first speaks for itself. It is, no doubt, the most serious objection to the system, and has deterred many from giving it a fair trial. I pass it by, however, as a point which occurs to every one, in order to conclude with a few remarks on the limits imposed by this material and method of construction on architectural design and decoration.

It is, of course, possible to build your plain walling in concrete, using quoins, window-dressings, strings, cornices, &c., of stone; but I refer to cases in which, from economical or other motives, an architect may desire to confine himself entirely to the use of concrete, without brick or stone In connection with this view of the subject, I take the first opportunity of protesting against the idea of a concrete arch. Concrete is in fact a solid mass of artificial stone, and it would be as rational to scoop out the underside of a York landing or a Portland stone lintel into an arched form to increase its strength as to mould a mass of concrete into such a shape with the same object. Concrete construction such as I have described is essentially monolithic, and the arch has no proper place in it, except perhaps as a mere decorative feature, evidently unconnected with the construction, if indeed, such a use does not carry its own condemnation. In saying this, I do not of course, refer to barrel vaults and domes which may properly be constructed as solid crusts or shells in concrete.

Wherever any architectural character or decoration has hitherto been attempted in concrete building, it has taken the form of the usual imitations of stone in Portland cement, and this has had the effect of increasing the prejudice against it as an encourager of stucco and shams. Now Portland cement stucco so far from being necessarily a sham, seems to me to be an admirable and useful material, which through long abuse has fallen into disrepute, but which is capable of perfectly legitimate treatment with very good results. We must not, of course, look for effects of light and shade produced by bold projections of cornices or string courses, nor for sculptured decoration; but we may get colour, and surface ornamentation, as for instance by incised stamped or *sgrafito* work, without the use of any other materials than concrete and cements. This is what we ought to aim at,

and whatever is done, the monolithic character of the structure should be borne in mind, and nothing should be allowed to twist it into forms and appearances foreign to its nature merely to make it look like other buildings.

For suggestions as to legitimate and artistic treatment of external plaster work we have plenty of examples, not only abroad, but in numerous old houses in all parts of our own country. Ornamentation of this kind could scarcely be so expensive as the elaborate cast imitations of stone which are usually employed.

I think, however, that in this system of building a great deal may be done without plastering the surface by using a fine concrete which may be kept to the external face of the work, and left untouched when the cases are removed. It is true that it is impossible for several reasons to avoid shewing the marks of the different levels at which the cases are fixed, but this being a necessity of the method should be made a feature, the marks should be clearly defined, and advantage might be taken of them to vary the colour and composition of the surface concrete. Finely broken granite or quartz, fine sea-shingle, and coloured sands may be suggested as materials for it.

In conclusion, without claiming for concrete building the extraordinary merits which it has been supposed to possess, I think it is a subject well worthy of the attention of Architects, and one which is capable of very great development, particularly in an artistic point of view, but in this direction nothing can be done so long as the only aim is to shew how well it can be made to imitate some other material and some other method of construction.

Professor KERR, Fellow, rose and said:—I have much pleasure in moving a vote of thanks to Mr. Wonnacott and to Mr. Blomfield for their papers. For my own part, I cannot but think that these papers will both be considered exceedingly well worth reading and studying. The material of concrete in the way in which it has been introduced to our notice this evening, is one of great practical interest to us. That it is a material which has a future is beyond doubt; whether it is capable of being brought into use for architectural purposes (artistically speaking), is a question which may admit of debate, but as regards its structural success, there can be no difficulty. We have been hitherto accustomed to look upon concrete as a material merely for foundations, and we are apt to forget that its use even in foundations is strictly this—that we thereby form a continuous slab or platform of *artificial stone*. It seems rather to surprise us, therefore, when we find it can be used as a wall; but why not? If you consider a great platform of concrete on which a building is to be erected as a horizontal slab, why should not, within reasonable limits, a similar slab be used vertically? The reason why we use the great concrete slab as a foundation is, that it is practically incapable of being broken by such pressures of cross-strain as we put upon it. The pressures on a vertical wall, are obviously much less. Therefore, with regard to the question of strength, it is manifest, theoretically, that concrete ought to possess very decided advantages over walls that are built in a fragmentary way of bricks or stones. The suggestions that have been made with regard to what I may call the incredible strength of concrete walls, have somewhat damaged the progress of the material. We are told that a very thin wall—even one of 6 inches thick—and that is an extremely thin wall—is equal in strength, not merely theoretically, but practically, by test, to our ordinary brick wall 9 inches thick. It is a pity that pretensions of this kind should be made, for this reason if no other, that we have no need of walls of less thickness than the ordinary standard of brick walls; and if a concrete wall can be built of the thickness of a brick wall, to serve the same purposes, with equal and possibly superior advantages, that of itself is all we ask for in favour of such a material, in order to consider it worthy of adoption. We know, for example, further, that a rubble stone wall has to be built of considerably greater

thickness than one of brick; therefore, as a concrete wall, in one sense, is a rubble stone wall of peculiar construction; it is plain that if the concrete wall can be built to advantage of the mere thickness of a brick wall, it must be allowed to possess considerable merits over and above those of the corresponding stone wall of ordinary construction. There are no doubt gentlemen present who are able to offer arguments in detail upon what Mr. Wonnacott and Mr. Blomfield have set forth in so interesting and practical a way; but, at the same time, it is doubtful whether the discussion of details here can lead to great advantage. Mr. Wonnacott has given the results of a large amount of experience, which he modestly underates, but it is obvious that he is speaking with a thorough knowledge of the subject, which, if not wholly derived from the proofs of time, is certainly due to careful study, on the basis of a very practical acquaintance with the working of the material. I will therefore offer no remarks upon details, except to say that we may, from recent examples, hope soon to see that concrete as a material for walling is a really good thing, and not merely to be employed in second and third rate works, but possibly applied even to works of greater importance.

Mr. J. Hebb, Associate.—We are indebted to Mr. Wonnacott for having given us independent views with regard to the use of concrete, concerning which we have had many conflicting opinions expressed. We have heard, chiefly from those who are interested in advocating the use of concrete, high-flown descriptions of the economy and usefulness of this material. Some of these statements have been adopted by practical men, and they have never been contradicted. It is well, now that we have had some experience of concrete, to look the facts in the face, and see whether there is any truth in these statements, and whether there is any chance that concrete will supersede bricks and stone for building purposes. First with regard to strength; considerable apprehension was entertained upon this head when concrete was first proposed, but experiment has shown that there was no ground of apprehension, and the strength of Portland cement concrete is now established beyond dispute. The supposed want of adhesion between the layers of concrete, which was at first supposed to be a difficulty in the way of its use, has been found in practice to be no obstacle, as perfect adhesion takes place between the separate layers. In order to confine the discussion within reasonable limits, I will assume that we are speaking of the use of concrete built in moulds, and not formed into blocks and built up with mortar, or cement, or other material. It is quite certain it is possible to build a wall of concrete in this manner, which shall be not only as strong, but probably stronger than a brick wall. The great tenacity and hardness which concrete walls acquire in a short time is remarkable. The extraordinary quickness of setting of Portland cement concrete is a thing one must see to believe; and the hardness it assumes in a short time can only be appreciated by practical experience. A builder told me a day or two ago it took a man three-quarters of a day to cut a hole about the size of a brick in a concrete wall, in order to put in an ordinary corbel. This will give some idea of the hardness of concrete. But when we come to other considerations, I think you will find that the advantages are not all on the side of concrete. If you take the test of appearance, I do not think any one who has seen a concrete wall would compare it with a well-built brick wall with regard to appearance. Nothing can be more forbidding than the concrete wall, with its large courses nearly 2 ft. deep; it is coarse, rough, uneven, and uninviting. It is impossible to leave the wall as it comes from the mould, and it is found necessary to render it with cement. The cottages built for the Exhibition lately held in Paris were expected to be a great success financially, but they were so unendurable that they were obliged to be plastered afterwards, at a cost which did away with the advantages which should have accrued from the method of their construction. Concrete walling is essentially cast in construction, and has all the appearance of having been cast. There is nothing of the agreeable appearance which belongs to work built up piece by piece. There is as much difference between concrete and brickwork with regard to the eye as there is between

cast-iron and wrought iron. You must cover the concrete over with something; and then comes the question, is it worth while? You may gain perhaps in the first cost of the wall, but in the end you are obliged to coat it with plaster, and make it look like an ordinary plastered wall. With regard to cost, I think the expense of concrete has been kept down in an unfair way. It is difficult to form grounds for comparison between one building and another. I may mention, however, that a concrete warehouse, erected under very favourable conditions, cost as much as $3\frac{1}{2}$d. per foot, while you can build a good brick warehouse for something like $4\frac{1}{2}$d. per foot cube. I have heard it stated by a practical man who was in a position to procure the materials at a moderate cost, that he had built a concrete wall 9 inches thick, 150 feet long, with only one pier at each end, at a cost of about 3s. 6d. per yard. That seems very cheap, but when examining the cost of materials, and putting down a proper amount for labour, I found that the cost of such a wall would be about 5s. a superficial yard. Now, if you take a brick wall 9 inches thick, with piers and ordinary footings—a perfectly good wall—that would come at £11. 10s. per rod (or to a little over 7s. per superficial yard); so that a brick wall does not cost so much more than a concrete wall. In the case of concrete, you have a rough wall; whereas, if the wall be built of brick, you have a perfectly well-finished wall. If you take one thing with another; if you look to appearance as well as cost, I think you will find on examination the average cost of concrete is not very much below that of ordinary brickwork. You may have seen in C. J. Richardson's book, 'The Englishman's House,' he puts the cost of a 9-inch concrete wall at 2s. per yard super, but you will find it is impossible to do it at any such low figure.

Mr. PAYNE, Associate.—I should like to ask, supposing you build the front wall of a warehouse, for instance, of brick, and the side and division walls of concrete, what would be the difference in the settlement, if any, between the brickwork and the concrete?

Mr. CHARLES BARRY, Fellow.—Nobody has risen to second the vote of thanks to the authors of the papers, and I do so with pleasure. I think the paper of Mr. Wonnacott is so full of practical information, given in the best and most useful way, that it is difficult at the moment to follow the various facts in the way they deserve. I could have wished that some of these apostles of concrete walls had been here to-night to tell their own story, because the weight of evidence has certainly gone against their pretensions. One of the greatest attractions in using an unfamiliar and new material or an old material in a novel form is economy. Mr. Wonnacott says, in an ordinary house the economy is only 10 per cent. on its total cost, and not always that. He has told us that the usefulness of this method of construction, and the prospect of its employment depends upon a number of circumstances not always easy to ensure, especially careful selection and preparation of the materials, and very careful supervision of the work. What little experience I have had has taught me the same lesson, and that the absence of that proper supervision, that constant, careful, conscientious supervision, will certainly produce the failures we have heard of. If that be so, it is hardly right to argue in favour of the use of concrete that it is a material which requires very little skilled labour in its employment. You want skilled labour of a high and conscientious order. He has also told us, that though he believes that concrete walls, well constructed, can be built with equal strength thinner than they could of brick, yet, from the nature of the moulds used, so far from economy of space being obtained, there is no power of expansion or contraction of the moulds, and that therefore a loss of space, and a want of economy therefore results in the upper floors of a building, because from the mode of making the moulds the walls are throughout obliged to be of the same thickness. As to Mr. Blomfield, he has entered into another part of the subject, viz.,—the adaptability of this material in an artistic point of view, and I think he has conclusively shown that it is very unadaptable for artistic treatment. All this being before us, I should have been pleased if those who are familiar with the subject, and enthusiastic upon it, had been here to give reasons for the

statements that have been published in various documents as to the use of this material for building purposes, as also for purposes which may possibly have not been treated of in these papers, and I say this on the principle of hearing both sides of the question. The papers of Mr. Wonnacott and Mr. Blomfield, when printed, will deserve every consideration, and if there are those virtues in the material which its advocates claim, the consideration of these papers, and the discussion they will provoke, will bring all necessary facts out.

Mr. T. Morris, Associate.—One application of this material for building purposes which may be mentioned is to columns. I took great interest in noticing some columns as they were built up a few years ago in porticos in the south-west portion of London. There was a thin iron core or bar as a support or stay for the work. Around that core was put a wooden casing, and between the core and the casing the Portland cement concrete was put in. The casing having been filled in in that way and left till the concrete was sufficiently set, was then removed, and after a short time a surface of stucco was put on, and the columns were finished in a very rapid manner. I expected to have seen those columns show signs of fracture; but after several years they appear to stand as well as stone columns would have done. That is one instance, I think, of the adaptability of the material to the ornamental parts of buildings. There is one point on which I would ask for information. I have lately had a flat roof covered in the ordinary way with concrete, and then faced with Portland cement; but rather to my surprise I found the workmen incorporating with the cement a certain modicum of coal tar. It was thought by them that it would have a good effect; but what it is really likely to be I should be glad to be informed. I should also be glad to hear some information with regard to the concrete walling which is being constructed on the bank of the Thames at Battersea Park.

Mr. Gilbert R. Redgrave, Visitor.—I have had a great deal to do with concrete, and I can only endorse the admirable remarks of Mr. Wonnacott and Mr. Blomfield. There is one subject with regard to the mixing which might well be discussed. It is customary to specify that the materials shall be turned over twice dry, and that then the water shall be added, either by a hose or as a fine spray from a watering can, and the ingredients turned over wet. Mr. Wonnacott says that this should be done twice; but it is astonishing how much better the concrete is if the sand be separated from the ballast at first by washing or by screening, and then be mixed with the cement and made into the consistency of mortar; into this mortar the proper amount of ballast may be introduced, say one part of cement to two or three parts of sand, made into mortar, to which from six to nine parts of clean ballast can be added. A much stronger concrete is thus made than with seven parts of ballast which contains the sand in the usual way, the shingle in which rarely ever gets to the cement. The adhesive of the loamy shingle, in fact, to the cement is so indifferent, that it is no wonder much of the concrete made with gravel never gets the strength of concrete made with river shingle. There is another point which has been noticed, namely, that too much reliance is frequently placed upon the quick setting qualities of Portland cement concrete. Last week there was a failure of a large amount of work from striking the frames too soon. This was on the Metropolitan District Railway at Brompton, and the concrete walling was carried up two feet thick to a height of twenty feet. The frame was the full height of the work, and the concrete was raised by a horse lift, and carried up day by day all in one stage. The most remarkable part of this wall was that the base was made of lime concrete for four feet high: there was a lime concrete foundation of 2 ft. 6 in. thick, and on that was put this high concrete wall 2 ft. thick. Five weeks after it was started they commenced to strike the frame work. The men began in the morning to take down the woodwork, and just before the breakfast bell rang 60 ft. of the side wall and the end gable fell in. Here it was thought that the whole of this work would have set in five weeks. This accident reminds us that thin concrete walls will set infinitely quicker than thick

ones, and there seems to be but little advantage in using thicknesses beyond 12 or 15 inches. Even when proper time is given to set thick walls, say of 18 inches, are not really much stronger than thinner ones, say of 12 inches; and in experiments upon the strength of this material it has been found that small blocks of concrete in from six to twelve months give relatively far stronger results than larger blocks of the same age; and the small test briquette now used, give an infinitely better result than cement moulded in lumps or blocks. The plan generally adopted of testing the cements, namely, making it up neat into small briquettes, is practically of very little value, as we never use it in this way, and the results, when it is mixed with a proper proportion of sand, bear no relation to the strength of the neat cement. The chief point placed before us to-night is the question of expense. I cannot say personally I can bear out the results which have apparently been obtained in the matter of cost. Of course the work I have been engaged on have not been houses or thin walls; but in ordinary cases I should say concrete walls would save a good deal more than the architect's commission. I have seen works at Chatham which seem to be remarkably good, where twelve parts of ballast to one of cement have been used, and I can quite believe that cement concrete, with ten or eleven parts of ballast, is stronger than that made with smaller proportions, say seven or eight parts. This is, perhaps, due to the fact that the cement, by being more intimately mixed with the sand in the larger proportion of ballast gets a better hold on the shingle than where the quantity of ballast and consequently sand is less. I have great pleasure in supporting the vote of thanks to the authors of the papers.

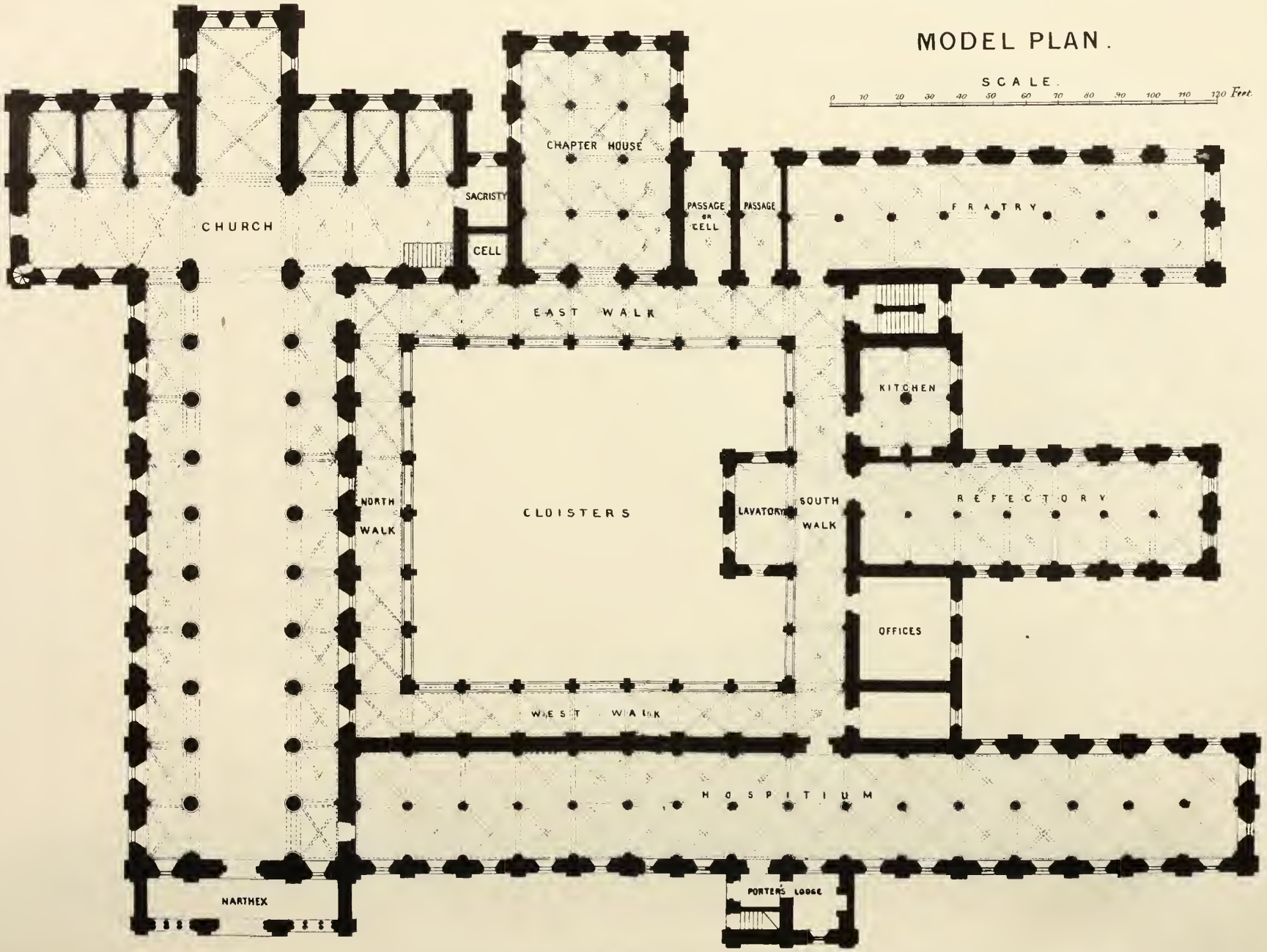
Mr. WONNACOTT, in reply to the enquiry of Mr. Payne, stated that the difference of settlement in a combined building of brickwork and concrete walls would depend in a great measure upon the thickness of the mortar joints in the brick portions. In some cases, he said, he had built the outside brick walls first, and the concrete walls were built in such thin layers, that there was no difference in the settlement, because they were built in such small portions at a time.

The CHAIRMAN.—Before putting the vote of thanks, I would say a word or two on this subject. I think probably I am the oldest user of Portland cement concrete in the room. The first time I used it to any great extent was in the Royal Exchange buildings in 1837, and I think that was one of the earliest uses of Portland cement concrete for internal works. I have been engaged upon perhaps some of the largest buildings in London which have been built in concrete; my friend Mr. Webb was engaged with me on those works, and there we have had an opportunity of testing it. I am convinced of what Mr. Charles Barry says, that unless you can thoroughly depend upon the honest and conscientious execution of the work by the contractor, concrete is a dangerous material to use, inasmuch as a small percentage of inferior material in Portland cement would cause the ruin of your entire work. In the case of a warehouse I superintended, the difference was not so great as was expected, notwithstanding the work was done under peculiar facilities. This concrete building is in Great Guildford Street, Southwark, and contains the largest capacity allowed for a warehouse building, namely 216,000 cubic feet. Mr. Wonnacott mentioned the great desirability of not using cement too newly made. I can testify to that. I have seen an instance in which the builder took the precaution to spread the cement in large shallow pans, and exposed it to the atmosphere for a time before he used it in the walls. You all know that the Metropolitan Board allow concrete buildings to be used in London, but they insist upon a considerable amount of iron hoop bond. I have, however, seen work in which the iron hoop bond has been omitted. Under the Metropolitan Board, you are not allowed to build of less thickness than brickwork, and therefore you cannot avail yourself of that saving which might otherwise be arrived at.

The vote of thanks to the authors of the papers having been unanimously accorded, the meeting adjourned.

CISTERCIAN ABBEY.

MODEL PLAN.



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Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, 19th June, 1871, the following Paper was read—
THOMAS H. WYATT, President, in the Chair:—

THE ARCHITECTURE OF THE CISTERCIANS.

By E. SHARPE, M.A., Fellow.

"Oppida Franciscus,—magnas Ignatius urbes,—
Bernardus Valles—montes Benedictus amabat."

INTRODUCTORY.

IT is perhaps not generally known that there exist in both the Universities of Cambridge and Oxford travelling fellowships, to which young men who have attained at the close of their academical career the degree of Bachelor of Arts are eligible during the first year of their bachelorship.

There are two such fellowships in the University of Cambridge. The persons who are elected to them are expected to travel abroad for three years, to select some subject for special study, and to send at the close of their term some account of what they have observed to the University.

I happened to be nominated and elected to one of these travelling fellowships in the year 1832. The subject which I selected as the one to which to devote my attention was that of Church Architecture. At an early period in the course of these travels, I was struck with certain peculiarities which I observed in the remains of the monasteries of the Cistercian order of monks, which led me to believe that they must have followed certain rules of their own, as well in the plan of their conventual buildings, as in the design of their churches. Further observation confirmed these impressions; I became interested in the matter, and so arranged my journies as to enable me, during the three years that I was absent, to visit nearly the whole of the principal Cistercian abbeys in France and Germany.

I have subsequently had opportunities of examining several in France that I did not previously visit, and the remains of nearly the whole of the English monasteries of that order; six of the abbey churches of which are illustrated in the work which I published in 1846, entitled 'Architectural Parallels.'

Some remarks of mine upon the subject of these peculiarities of style and structure were published in a local lecture soon after my return from the continent in 1836, as well as in a lecture to the Cambridge Camden Society, and others have subsequently appeared at different times, notably in Mr. Beck's work, 'Annales Furnesienses,' published in 1842; and others in the 'Journal of the Archæological Association' for 1850, and in a lecture delivered to the Archæologieal Institute in 1868.

The terms and descriptions contained in these accounts have in the interval been used by other writers, and the conclusions which I formed many years ago on the subject appear to be now pretty generally admitted and adopted; but as I have never yet been able to realize my intention of devoting a special work fully illustrated to this special study, it appeared to me, when the Council of the Institute requested me to deliver to the members during the present session a lecture on some subject of archæological interest, that I could not better answer their request than by endeavouring to place

before you in rough outline, and in the general manner which is suitable only on such an occasion, the results of my observations on this special branch of architectural study.

Historical.

The three principal monastic orders of the Middle Ages were: I. The Benedictine; II. The Præmonstratensian; and III. The Cistercian. Of these three orders the Cistercian, which was an offshoot from the Benedictine, was the latest.

The order arose in the west of France at the close of the XIth Century, and was instituted by three monks of the Abbey of Molesme in Burgundy, who, grieving over the general laxity and want of discipline that prevailed in the Benedictine abbeys, and more especially in the one to which they were attached, after several fruitless efforts to reform and correct it, quitted their convent, and retiring to a desert and secluded spot in the diocese of Chalons, established there, with the favour and under the protection of Otho Duke of Burgundy, in the year of our Lord 1098, the Convent of Citeaux, where they lived after a new and stricter rule, founded upon that of the order of St. Benedict.

Great, however, as became in a short time the reputation for sanctity of these early founders of the Order, and favoured as were their efforts, not only in the establishment of Citeaux, but also of several dependent abbeys, it is to the great St. Bernard that the extensive renown and rapid increase of this Order is to be attributed.

He appears to have entered the Abbey of Citeaux in the year 1112, and to have been sent with twelve monks to occupy the new Abbey of Clervaux, as its abbot in the year 1119. He was one of the greatest luminaries of the Church; his zeal, his piety, and his learning were such as to obtain for his particular Order, to which, as one of its earliest votaries, he was devotedly attached, the greatest favour and support. During his lifetime a very large number of monasteries were founded, built, and endowed.

The Order continued to be exceedingly popular and prosperous until the end of the XIIIth Century, when the same laxity, which had corrupted the other orders, began also to affect the Cistercians, and we find them ultimately departing from the precepts of their founders, not only in regard to external forms, but also in their discipline—a departure as apparent in the style of their buildings as in their mode of life.

A considerable number of the abbey-churches of this Order remain at the present day, and although subsequent extension and alterations have in many cases swept away the original structures, still a large portion of those that are left are the early buildings of the XIIth and XIIIth Centuries, and belong to the period when the whole of the rules of the Order were fully enforced. In France they are the most abundant, in Germany many valuable examples still exist, and in England they are to be reckoned amongst the most interesting of our monastic remains. I need hardly add, that in all three countries they are chiefly in a state of ruin, except where they have been devoted, as occurs in some few cases, to some secular purpose. Their ruinous condition, however, increases rather than otherwise, the interest usually taken in them, and certainly adds very considerably to their picturesque effect, and to the facility with which their mode of construction can be studied.

The most authentic records which remain to us of the acts of the Cistercians, and of the early history of the Order are contained in two chronicles, the first and earliest of which is known as the 'Magnum Exordium Cisterciense,' the date of the compilation of which seems uncertain, and the 'Parvum Exordium,' which was written in the year of our Lord 1120, by one of the elders of the Abbey of Clervaux. According to these histories, the first statutes of the Order were composed by Alberic, the second abbot of Citeaux, and published by him in 1001, the year after the new Order had

been confirmed by Pope Paschal. These related principally to the diurnal duties of the monks, their dress, diet, and mode of life. They were subsequently enlarged by Stephen, the third abbot, who added particular instructions in regard to the utensils and furniture of the church. The most important, however, of all the statutes of the Order was the famous 'Charta Caritatis,' the bond of brotherhood which united the whole of the existing and future abbeys of the Order under a code of laws well designed to insure unanimity and conformity throughout the whole of the Cistercian community. This Charta Caritatis was composed and edited by Abbot Stephen at the request of his brother abbots, and was confirmed and published in the year of our Lord 1119, at a general chapter of the Order, which was attended by the abbots of all the then existing Cistercian monasteries.

At several subsequent periods the institutions of the Order were revised and reinforced by general chapters, and several particulars of practice and discipline more especially noticed than appears to have been considered necessary in the earlier statutes. One of these republications took place in the year 1134, when the whole of the precepts and observances of the Order were collected in one volume, consisting of eighty-seven chapters, compiled and edited in all probability by St. Bernard himself. It is chiefly from this document that the quotations which I may have to make this evening will be taken, and as they will be limited to such as relate only to their buildings and churches, and are few in number, I must refer any one who may wish to enter into the interesting details relating to the rule of life, discipline, habits, and other matters, to the following works, which contain the fullest particulars of the early history of the Order:—1. 'Chronicon Cisterciense,' by Miræus, 1613. 2. 'Menologium Cisterciense,' by Henriquez, Antwerp, 1630. 3. 'Annales Cistercienses,' by Angelo Manrique, Lugduni, 1642. 4. 'Nomasticon Cisterciense,' Paris, 1664.

I have already spoken of the large number of the abbeys of this Order, but it was not until the year 1128, that is to say thirty years after the foundation of Citeaux, that they began to increase with any degree of rapidity, and this increase was probably due as well to the great and increasing reputation for sanctity that the monks of this Order had acquired, as to the rising reputation and influence of St. Bernard, who had then been nine years Abbot of Clervaux. Within 200 years of that date, no less than 1200 abbeys had been founded, erected, endowed, and added to the Order, and the entire number of dependencies possessed by the Abbot of Citeaux shortly before the Reformation is stated to have been 3,200. Now of those 1,200 monasteries I do not know one the general plan of which is not in accordance with that of all the rest; nor a single church, which does not bear in its details the impress of its Cistercian origin. This remark, limited as you will notice to the monasteries that were erected during the first two centuries of the existence of the Order, applies, of course, only to the general disposition of the monastic buildings and to the general character of their architecture; variations occur, as a matter of course, as well in the one as in the other, due to local or other causes, but they are mostly of slight importance, and are, in fact, of the nature of those exceptions which tend rather to prove the general rule than to invalidate it.

Of these peculiarities some are the result of positive directions contained in the statutes of the Order already referred to, whilst some appear to be matters of habit and practice, as strictly observed, however, as if they were enjoined by the written rules of the Order. I will refer to them indifferently, and in the order in which they present themselves most conveniently for the rapid survey which we can only take of them this evening.

Descriptive.

But here I encounter a difficulty which appears to be almost insurmountable; it is the difficulty which the French—with that felicity of expression and quick turn of thought, which has enabled us to enrich our language by borrowing so many phrases from theirs, for which there is no equivalent in

English—it is the difficulty which the French call the *embarras de richesses*, the difficulty, in fact, to know how, within the hour that is at my disposal, to lay before you an outline even of the varied topics of interest that the practice of the Cistercians presents to us from an architectural point of view.

Indeed I hardly know which of two apologies I ought to make to you to-night; whether I ought, in fact, to apologize for having put too many or too few drawings upon the walls. We have here the ground-plans of some eighteen of the principal abbey-churches of this Order in Europe, with as much of their conventual buildings as remain. Now any one of these groups of buildings is capable of contributing not a line, or a single page, but a whole volume of historical matter on this subject, and is of sufficient interest and importance to occupy our entire attention for the whole evening, whilst, on the other hand, these eighteen abbeys, although perhaps amongst the most important and complete of their kind, do not represent even a hundredth part of the valuable remains, existing, for the most part, in a fragmentary but still very interesting condition in various parts of the world.

There are limits, however, to our possibilities in a lecture of this kind. The whole of these diagrams have been prepared within a brief period exclusively for the purposes of this lecture, and entirely from materials in my own possession, or from measurements recently made for me, with one or two exceptions, which I will notice in their place. You must bear in mind also that these are not competition drawings, prepared by a set of ardent young architects, regardless of expense, ready to devote their money and their time to the service of an ungrateful public, in the hope, each one, of gaining a prize and achieving high renown. Without dwelling, however, on the vanity of this hope, and only reminding you that these drawings have been prepared with a very different object, I will venture to ask you, having mentioned the word "competition," whether the whole of the plans on these walls do not, after all, look very like competitive drawings? Whether it might not be easy to believe that they had all been produced by architects, each acting separately under the stringent orders of a very arbitrary committee, and under the pressure of the belief that if they departed in any respect from the rules laid down to them, their plans would be laid aside and excluded from the competition?

Well, I believe, after all, that that impression represents pretty nearly the true state of the case. In fact, my first business to-night is to draw your attention to this remarkable uniformity in the designs of the Cistercians; to explain some of its causes, to enter into some little detail for this purpose, and, as the clock warns me, to do this in the most rapid manner possible.

Site.

The first thing that strikes us on approaching one of the abbeys of the Cistercians is the nature of its site. They appear to have invariably selected remote situations at a distance from towns, generally in a valley, and in the narrowest part of the valley, with a view, apparently, to complete retirement and seclusion. In France and Germany this appears to have been the almost invariable custom of the Cistercians. In England, situations of this kind were, perhaps, more difficult to meet with; still I know of no single instance in this country even, in which this general practice has been departed from, or the valley deserted for the high land.

We turn, then, with interest to our chronicles to ascertain whether a practice which appears to have been so universally followed, was enjoined by any specific rule; and we find, on consulting the Statutes of the General Chapter of 1134, the following instructions, which forms the subject of the first chapter of these Institutes, as given in the 'Nomasticon Cisterciense,' p. 246:

"Cap. 1.—*Quo in loco sunt construenda Cœnobia.*

"In civitatibus, in castellis, aut viliis, nulla nostra construenda sunt cœnobia sed in locis a conversatione "hominum semotis."*

* Instituta Capit. gen. Ordinis Cisterc. A.D. 1134. Cisterc. 36, Nomasticon Cisterciense. Julianus Paris. Paris, 1664, p. 246.

Plan.

With respect to the plans of their conventual buildings, their relative disposition, form, and respective uses, the distinctive mode of treatment and the amount of decoration which each separate building received, there are, as might be naturally supposed, no special instructions in their statutes; there is, however, in point of fact, a uniformity of observance in all these respects, which, to say the least, is very remarkable, and which deserves our special attention. This uniformity is, indeed, such as to enable us to show upon a typical plan—such as the one here exhibited—a true representation of the whole of the normal buildings that surround the cloister quadrangle of a Cistercian monastery of the XIIth Century. I propose, then, to point out to you, upon this plan, the relative position and the respective use of each of these buildings, and will afterwards point out, on the plans of the different abbeys which are on the walls, in what respect their existing remains correspond with, or vary from, this normal plan; and I will notice as I proceed some of the particulars in which the style of their buildings, and especially that of their churches, was governed by the rules of their statutes and of their practice; and although there are some which, being smaller and not so complete as others, do not contain the whole of the buildings shown on this plan, there is not one of that date, the original disposition of which does not exhibit an approximation more or less close to this model plan.

I.—The Church.

Of the general buildings the church was of course the most important. The rules in regard to it were formal and numerous: amongst others the following are the most remarkable.

They were all dedicated to the Blessed Virgin.

"Cap. XVIII.—*Quod omnia monasteria in honorem Beatæ Mariæ dedicentur.*

"Quia antecessores nostri et patres de ecclesia Molismense, quæ in honorem Beatæ Mariæ constructa est ad "Cisterciensem locum, unde et nos exorti sumus, primitus venerunt; idcirco decernimus ut omnes ecclesiæ nostræ "ac successorum nostrum in memoriam ejusdem cœli et terræ Reginæ Sanctæ Mariæ fundentur et dedicenter."*

They were also all built after the form of the cross:—

"Omnes ecclesiæ ordinis nostri in honorem Beatæ Mariæ dedicatæ sunt, et fere in modum crucis constructæ, "instar Ecclesiæ Cisterciensis omnium matris."†

The Choir was invariably short, seldom containing more than two compartments in length beyond the Crossing; and if that part of the plan of one of these early Cistercian churches, which represents the choir, the transepts, and the nave, exclusive of chapels and side aisles, be tinted with a slight shade to distinguish it from the rest, it will be found to depict very exactly the form of a true Latin cross.

The east end was usually square, and not terminated with an apse; showing a marked departure from the manner in which churches of this date on the Continent were usually finished towards the east. Towards the close of the XIIth Century, however, the prevailing fashion of the times was introduced also into some of the churches of this order, and the apse, with its accompanying chapels, applied to the east end. Whether the church of Clervaux Abbey, which was rebuilt on a grand scale by St. Bernard himself in the middle of the XIIth Century, was originally thus finished or not appears to be uncertain, for the building has been subsequently much changed and modernised, and being used at present as a gaol is difficult of access; I am unable therefore to say whether the plan which I have of it represents its original condition or not: if it does, it was in all probability the first

* Nomasticon Cisterciense.

† Ritulum Cisterciense. ex Libro usuum definitionibus ordinis collectum. Paris, 1721, p. 5, chap. iii.

of these churches built with an eastern apse and radiating chapels. BROMBACH and ALTENBERG are the only German exceptions to the rule that I know of, and CROXDEN and BEAULIEU the only English ones.

FONTFROIDE has, singularly, a polygonal apse to its choir, and one to each of its transeptal chapels; and PONTIGNY has an apse planned very like that of CLERVAUX.

The Transepts had no aisles, but invariably two or three chapels on their east sides, completely separated from one another by partition walls in the earlier examples. Each of these chapels had its altar and its piscina. In most of the ruined abbeys of this order the site of these altars is apparent; and at JERVAULX Abbey in Yorkshire two of the altar stones remain *in situ*.

In many of the Cistercian churches we find a portico or narthex extending across the whole of the west end of the church. It had no great width, and was generally roofed as a lean-to against the west wall, and covered the west doorway, as at FOUNTAINS and BYLAND; but in some it was vaulted, as at MAULBRONN and PONTIGNY. Its use is not very obvious.

We find no lofty towers in Cistercian churches, except such as were built after the rules of the order became relaxed, as at FOUNTAINS and FURNESS, where towers were added in both cases towards the close of the Rectilinear Period: they were, in fact, expressly forbidden in the General Chapter of 1134.

"CAP. II.—*De turribus ad Campanas.*

"Turres lapideæ ad campanas non fiant, nec ligneæ altitudinis immoderatæ, quæ ordinis dedeceant "simplicitatem."*

And again with respect to bells we find:—

"CAP. XII.—*De Campanis.*

"Campanæ ordinis nostri ita fiant ut unus tantum pulset eas, et nunquam *duo simul*. Notandum autem "quod cum sit intervallum inter laudes et Primam, modice debet pulsari major campana."†

These wooden Bell-turrets existed in most of the early French Abbey Churches of their order, over the Crossing. There is a representation of such a turret so situated in an early engraving of the church at Citeaux, before it was destroyed: and there is one existing at Brombach, with a small circular opening beneath it, in the apex of the western arch of the Crossing, through which the rope descended to the floor of the nave.

In England the four walls of the Crossing were in many cases carried up above the roofs of the four arms of the cross, and covered with a low pyramidal roof. At Kirkstall this low central lantern still exists.

The Cistercians absolutely prohibited the carving or representation of the human form in their buildings, and give a reason for it which deserves consideration even at the present day.

"CAP. XX.—*De sculpturis, et picturis, et cruce lignea.*

"Sculpturæ vel picturæ in ecclesiis nostris seu in officinis aliquibus Monasterii ne fiant interdicimus: quia "dum talibus intenditur, utilitas bonæ meditationis vel disciplina religiosæ gravitatis sæpe negligitur; cruces "tamen pictas, quæ sunt ligneæ, habemus."‡

We accordingly find in none of the abbey churches of this order the representation of a human head or figure carved in stone, whereas they abound in the contemporaneous buildings of the other orders. I do not remember to have seen—and I have searched for it—a single exception to this rule in the numerous abbey churches of the Cistercians that I have visited in Europe, constructed during the first two centuries of the existence of the order.

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* Nomasticon Cisterciense, p. 274. † Nomasticon Cisterciense, p. 274.

‡ Nomasticon Cisterciense.

They prohibited, indeed, all carved works of a superfluous or highly decorated character in their buildings, and all pictures, except those of Our Saviour; and directed that diligent enquiry should be made into these matters at the periodical visits of the abbots, so as to ensure the observance of the rule.

" Superfluitates et curiositates notabiles in sculpturis, ædificiis, pavimentis, et aliis similibus quæ deformant " antiquam Ordinis honestatem, et paupertate nostræ non congruunt, in Abbatiis, grangiis vel cellariis nostris " ne fiant interdicimus; nec picturæ præter imaginem Salvatoris. Hæc omnia patres Abbates in suis visita- " tionibus diligenter inquirant, et faciant observari."*

They prohibited stained glass, except in such abbey churches as had belonged to other orders, and in which it existed previously to their conversion.

" Vitriæ albæ tantum fiant, exceptis Abbatiis quæ alterius Ordinis fuerint, quæ aliter factas tempore suæ " conversionis habuerint, poterunt retinere."†

They permitted only Royal personages and bishops to be buried in their churches. Their abbots were interred in their chapter houses, and the common monks in the cloister quadrangle.

" Cap. XXV.—In majoribus ecclesiis nostris non sepeliantur nisi Reges et Reginæ et Episcopi; in Capitulis " vero Abbates et prædicti si maluerint, et lapides qui positi sunt super tumulos defunctorum in Claustris terra " exœquantur, ne sint offendiculæ pedibus transeuntium."‡

The Cistercians were amongst the first to employ and to utilize the pointed arch in their arches of construction, whilst their arches of decoration remained circular. There is not one of the conventual churches of the XIIth Century given in the list at p. 16, in which this rule, to which I have so frequently called attention, was not observed; the main arches of the Piers, the Crossing, and the Vaulting being pointed, and those of the Doorways, the Windows, and the arcades being circular.

Having thus described the Church and its principal features, and accounted for the extreme simplicity observable in its architecture throughout the whole of Christendom, we will proceed to examine the conventual buildings in the order in which we shall find them, in passing out of the church by the door which opens into the east walk of the cloisters, and, following the latter, pass round the whole, until we arrive at the west end of the church:—and here it may be remarked, that the conventual buildings of a Cistercian Abbey were usually placed on the south side of the church, which was generally the first building constructed, and against the wall of the south aisle of which, the north walk of the cloister was commonly built. There were, however, occasional exceptions to this rule, caused often by peculiarities of site, of which Tintern in England, and Fontfroide in France, are instances,—in both of which the conventual buildings are placed on the north side of the church.

I know of no monastic remains of this Order in England, in which the cloister, or any part of it, is left. At Fontenay in France—the counterpart of Fountains in England—there is a magnificent cloister of early Transitional character, in perfect preservation. Vallemagne and Fontfroide retain also their cloisters, but of later date. At Brombach in Germany, the cloisters still remain, but in that country, as in England, they have almost completely disappeared.

The access from the church to the cloister was by a doorway facing the east walk of the cloister, in the wall of the south aisle where it joins the south transept. This doorway remains in almost all the Cistercian churches that are left in the three countries.

II.—The Sacristy. Vestiarium.

Close adjoining the church, on the south side of the south transept, was the Sacristy. The access to it was usually by a doorway in the south wall of this transept, and by no other: it was lighted by

* Capit. Gener., anno 1213, cap. iv. Nomasticon Cisterciense.
† Idem, Cap. Gen.. ‡ Idem

a window in the east wall, and was invariably vaulted. Sometimes it was approached from the cloister, and not from the church, and had a doorway in its west wall; in which case it occupied the whole of the narrow space between the transept and the chapter house, as in Jervaulx Abbey. More frequently, however, we find this space divided into two portions transversely, separated by a partition wall, the eastern portion being the sacristy, and the western a cell, the use of which cannot be pronounced with any degree of certainty.

III.—The Penitentiary.

It has been suggested that the cell just mentioned was used as a sort of morgue or dead-house, in which the bodies of the monks were deposited during the interval which elapsed between their death and their burial. It appears to me from various circumstances, however, to be much more likely that it was used as a place of confinement for monks condemned in the adjoining chapter house for some of the numerous small offences which rendered them liable to this punishment. The doorway which opened to it from the cloister was usually quite plain, and was rebated and prepared for a door that was capable of being securely fastened, which was not the case with many of the other openings. This cell was, like the sacristy, usually vaulted, but quite plainly; it had no window. Reference is sometimes made in early chronicles to a place of confinement called the Lantern; the offender is said to be placed "in Lanternâ." Was this cell the penitentiary of the convent, and was it called the lantern in jest; "Lucus à non lucendo?"

In some cases the partition between the sacristy and this cell has, at a later time, been removed, as if the use for the latter no longer existed; and in some the vault runs through, and the partition appears to have been constructed subsequently. In other cases again, both the sacristy and the cell occur side by side, between the transept and the chapter house. In Furness Abbey, there are two such cells, one on each side of the vestibule of the chapter house.

IV.—The Chapter House. Capitulum.

We next come to the Chapter House, the building which ranked next to the church in importance, and the architecture of which was always of a superior character to that of the other conventual buildings. Its axis lay uniformly, like that of the church, east and west. It was usually divided transversely into three equal portions by circular or clustered piers, and was invariably vaulted with well-moulded vaulting ribs, springing from elegant clustered piers and moulded capitals. It was approached from the cloister by a large archway, having on each side of it similar arched openings resembling windows, but which sometimes came also down to the ground, but usually were finished like windows with a sill about 3 feet above the floor. None of these openings were closed; the doorway, if it may be so called, was not prepared for a door; nor the windows for glass or casements. The chapter house was therefore open to the outer air, for the cloister itself was so; a circumstance which is quite in consonance with what we know of the hardy habits of these Cistercian monks.

This triple arcade, of which the side arches had usually double arches, is one of the most striking features in the cloisters of a Cistercian convent. We have excellent examples at Kirkstall, Fountains, Buildwas, Furness, Calder, Croxden, Jervaulx, and Netley, England; in Fontenay, Vallemagne, and Font-froide, in France; and in Maulbronn, Brombach, and Altenberg, in Germany.

The Chapter House was lighted chiefly by the east windows, one at the end of each of its three aisles; but also by north and south windows in such of its compartments as projected beyond the adjoining buildings. The Abbot's seat was in the centre of the east wall, and the monks were ranged round the building on one or more rising stone seats ranging along the north and south walls: these

stone seats are still left in the chapter houses of FOUNTAINS and JERVAULX; and might be discovered, no doubt, in many others, if searched for. The Abbots were buried in the chapter house, and their tombstones, level with the floor, have been discovered in most Cistercian abbeys; a considerable number were found at FURNESS, and are still preserved in the abbey grounds. In one Cistercian abbey only with which I am acquainted, is the form of the chapter house other than that of a parallelogram; at MARGAM in South Wales, the chapter house is octagonal.

V.—PARLOUR. LOCUTORIUM.

We have next a narrow apartment, which, as it appears in many cases to have had a door at each end, has been supposed to be the locutorium or parlour, in which the monks were allowed by special permission of the superior to converse with relatives or friends. Knowing the stringency of Cistercian rules, which enjoined almost perpetual silence, and being doubtful whether, in many cases, the access to the outer of these two doorways would be a convenient one for strangers, I have a difficulty in accepting this designation; but having no better to offer, will allow it to stand, until further light be thrown on the subject—it was invariably vaulted, and generally quite plain.

VI.—PASSAGE.

Adjoining the latter apartment, where it exists, we have invariably a passage leading direct from the cloisters into the precincts on the east side of the buildings. Where the Abbot's Lodge was on this side, as appears to have been frequently the case, this was no doubt his means of approach to the centre of the Convent, the Chapter House, the Refectory, and the Church. It is always vaulted, and usually treated in a superior manner. Interesting examples occur at FOUNTAINS, JERVAULX, CROXDEN, FONTENAY, and BROMBACH.

In some cases only one of these two apartments—the passage, namely—exists; and in others both have the appearance of passages, although their distinctive designation in this case appears difficult to assign. In others, again, their relative position is changed, the passage being next the Chapter House, and the apartment next the Fratry, as at KIRKSTALL. It must be said, however, that these two apartments seldom remain at present in their original condition; an eastern doorway in some having been converted into a window, and occasionally a window into a doorway.

VII.—THE FRATRY.

The last building to which access was obtained from the east walk of the cloisters was the Fratry, the ordinary day-room of the monks, which, with its axis lying invariably north and south, extended considerably to the south, beyond the adjoining buildings, and was therefore well lighted. Unlike the Chapter House, it had a single row of piers only—usually circular or octagonal columns—carrying plain quadripartite vaulting, without groin ribs; indeed the whole apartment was treated in the plainest manner possible, in strong contrast with the Chapter House and Refectory.

Not only was this living room of the monks unfurnished with a fire-place, but what is more extraordinary, we find, in two examples at least, indications which prove clearly that the extreme south end of this building was not closed. At FURNESS the two southernmost compartments of the Fratry—one of the longest and finest in Europe—have arched openings in their north and south walls in place of windows. These openings descend to the ground, and were evidently originally not closed; similar openings, similarly finished, occur also at the extreme south end of the building; so that this end of the building must have been open to the outer air during all seasons, night and day, a circumstance which gives us an idea of the austerity of the life that these hardy monks lived in the 12th century. But what is equally striking is the fact, that their successors in the 14th not only filled up these four openings, but inserted fire-places in two of them, bearing marks in their details which leave no doubt of the date of their construction.

In Jervaulx Abbey the end wall of the Fratry was similarly treated and carried on two open arches resting on a central pier, which contained on its north side the respond pier of the central line of arches, and on its south side a buttress to resist their thrust, leaving thus no doubt that the monks of this abbey lived also during the day-time in the rigour of a northern climate, exposed to the influence of the outer air.

At Croxden the south end of the Fratry, although partly destroyed, has the appearance of having been constructed in the same way with two large openings instead of windows.

The Fratry, always similarly treated, as to its details, and similarly placed, exists still in the remains of a large number of the abbeys of this Order.

VIII.—Staircase.

Next to the Fratry and on its west side we usually find the stairs which led to the monks' dormitory, which was over it, and which we shall notice presently. Under these stairs occur sometimes stone lockers and closets, which may have been used as cellars.

IX.—The Kitchen.

The first building entered from the south walk was the kitchen, which usually had two large fire-places in its east and west walls, and sometimes more; at Jervaulx, where it is later, and otherwise placed, there are four, occupying each one of the four sides of the building; at Fountains there are two of prodigious size, the horizontal arches of which are formed of joggled stones, four feet six inches in length. Bearing in mind the simple diet of the Cistercians, this surprising provision of cooking power at first surprises us, but when it is borne in mind that these monasteries were the caravanserai of the country in those days, and when the size of the Guest House and its dormitory are regarded, and the scale on which their hospitalities were carried on, is considered, we have no cause to wonder at the size of these fire-places. Excellent and early examples of Cistercian kitchens exist at Fontenay, Brombach, and Rievaulx Abbeys, which preserve still their deep and wide fire-places, their funnel-shaped chimnies, and their circular stone chimney shafts at the top.

X.—The Refectory. Refectorium.

In the centre of the south walk, and with its axis running north and south, was the Refectory. It was the building which, after the Chapter House, had the greatest pretension, and was finished with the greatest attention to its architectural details. In the other orders we find the Refectory usually placed along-side the south walk of the cloister, with its axis running east and west; in the Cistercian convents it is placed, on the contrary, as already described, always north and south. It is generally a very elegant building, with a single row of columns down the centre, supporting a wooden roof, and rarely vaulted. It had almost invariably an arched recess or gallery on its west side, reached by a flight of stairs in the thickness of the wall, the approach to which from the Refectory, was by a doorway in the wall itself; in the front of this gallery, facing the east, was a pulpit or stone desk, from which one of the monks read portions of the scriptures during the hour of refection.

Beautiful examples of this staircase, gallery, and pulpit, more or less elegantly ornamented, occur at Beaulieu in Hampshire, Fountains, Rievaulx, Tintern, and Hailsbronn in Germany. At Fountains the stone locker where the books were kept, and whence they were taken by the reader, as he entered the doorway, exists still at the foot of the stairs.

XI.—The Lavatory. Lavatorium.

Close adjoining the Refectory, either in the south wall of the south walk, or in a small separate building opposite the Refectory doorway, was the Lavatory; we find it in the latter situation at Fon-

TENAY, where it formed part of the original design, and at MAULBRONN, where it was erected at a later epoch; it consisted in these two cases of a large stone basin, placed in a small vaulted building, which, in the former case, was square, and in the latter octagonal; and at THORONET in France, hexagonal. At FONTENAY this building has been destroyed, but the indications of its existence are sufficiently clear; at MAULBRONN it still remains, as well as the basin.

But the more usual situation of the lavatory was in the south wall of the cloister; at RIEVAULX Abbey, it extended along this wall on both sides of the refectory doorway, and was covered by a handsome circular arcade; the channel for the overflow, and the drain from it remaining still. At CROXDEN and FURNESS Abbeys, though the refectory itself has, in both cases, disappeared, ornamental remnants of the lavatory still exist, as well, in the latter case, as the drain which carried off the water.

XII.—OFFICES.

Between the refectory and the next chief building that we have to describe, are usually found one or two apartments the exact nature or use of which I am unable to state;—they may have been cellars, or store-rooms, or offices of some kind. I have been unable as yet to discover any certain indication of their use and destination, and will not therefore pretend to name them. At KIRKSTALL there is in this situation a very large circular arch, which looks more like that of a gateway entrance than anything else, though that it was so is highly improbable.

XIII.—HOSPITIUM. GUEST-HOUSE.

The last and most important building that we have to examine on the ground floor is that which occupies the whole of the west side of the cloister quadrangle, and usually projected far beyond it. There can be little or no doubt that this was the Hospitium or Guest-house of the convent, where the whole of the travellers, of every degree, passing through the country, were received and entertained in the daytime, and over which, in the story above it, they were housed and lodged at night. This was generally the longest building in the Monastery, measuring, in some cases, upwards of 300 feet in length. It was planned like the other two secular buildings already noticed—the Fratry and the Refectory—with a single row of columns, usually circular or octagonal, throughout its entire length, carrying simple quadripartite vaulting, the perspective effect of which, in the long vistas of FOUNTAINS, BROMBACH, VAUCLAIR, and others, is particularly striking. It is usually a low building, the piers not often exceeding 4 or 5 feet in height. The Hospitium at FOUNTAINS, which is vulgarly supposed to be the cloisters, is a remarkable example, and is one of the longest that I know. At FURNESS an almost equally interesting one has been recently discovered, the piers of which are only 3 feet 6 inches in height. In some few examples this building appears to have been originally divided by partition walls into two parts, probably for the sake of distinguishing between guests of different classes; and it seldom happens, where it was originally undivided, that it remained so up to the dissolution of the monasteries. These subsequent divisions, therefore, must be distinguished from those which formed part of the original design, and which, as I have already said, are very rare. At MAULBRONN, however, the Hospitium was thus divided, one of its portions receiving a much more ornamental treatment than the other.

In some cases we find a small building attached to the Hospitium on its west side, the nature of which at FOUNTAINS, is too obvious to permit us to doubt its use. It consists of a small room, having a fire-place in it, and a covered porch for approach, with a flight of stone stairs at its side, passing over it to the upper story of the Hospitium. This was evidently the porter's lodge and living room, who thus guarded with his dog—whose kennel was as evidently under the first flight of the stairs—the approach to the Guest-house.

An entrance to the church was always provided for the guests from the Hospitium, either by a doorway direct from the latter to the south aisle of the church, or by one at the west end of the south aisle.

The Hospitium was lighted throughout its entire length by windows on its west side, one in each compartment,—as well as in its south or end wall, and partially also in its east wall; nor can we fail to observe, how admirably the general disposition of the buildings in this early plan of the Cistercians, is adapted to the admission of light and ventilation to the three principal buildings of the convent, the Hospitium, the Refectory, and the Fratry.

We have still to notice the apartments of the upper story of this range of building. They are principally three; and exist only over those buildings that below are vaulted.

XIV.—The Guests' Dormitory.

This apartment was usually a long undivided chamber over the Hospitium, to which access was obtained either by a newel staircase in one of its walls, or by a staircase planned like that I have already described as situated between the Fratry and the kitchen. It had a range of windows on each side, corresponding with those below, and was usually covered with a wooden roof; but at Vauclair, in France, the Hospitium and Dormitory correspond in every respect, both being elegantly vaulted, and having each a row of columns with floriated capitals throughout their entire length, and double circular-headed windows in each compartment; the whole forming a noble range of building, with high-pitched gables at each end, and a fine wooden roof above the upper vaulting.

Access to the church was occasionally provided also for this dormitory by a flight of stairs at its north end. Sometimes, however, an opening only, or archway at this end, into the upper part of the aisle wall, permitted the guests, without leaving their beds, to hear the nightly services of the monks.

XV.—The Monks' Dormitory.

This apartment was similarly situated over their day-room, and was approached by the staircase already noticed as existing between the Fratry and the kitchen. It was treated in as plain a manner as the Guests' Dormitory, which it resembled in all respects, having usually a wooden roof; but at Altenberg it is handsomely vaulted, like the Fratry.

XVI.—Library. Scriptorium.

From the Monks' Dormitory it was absolutely necessary that there should be ready access to the church, their rules obliging them to enter it for their orisons every four hours. This was obtained by covering the whole of the vaulted buildings that intervened between the Fratry and the South Transept of the Church with a second story, the floor of which was on the same level as that of the Dormitory, and by adding a flight of stairs in the South Transept of the Church, against its west wall. In some of the earlier buildings we find a newel staircase to have been first constructed in the middle of the south wall of the South Transept, as at Fountains, but this mode of access seems almost uniformly to have been subsequently abandoned for the more convenient and straighter access afterwards introduced. There is scarcely a single Cistercian Church which does not contain this staircase, or traces of its existence.

But the second story of the Chapter House was appropriated to another and very important purpose; it was used as the Scriptorium or Library, where the books were kept, and the MSS. written and illuminated. It was the room in which, in all probability, the more zealous, intellectual, and accomplished of the monks spent the greater part of their time. I do not know a

single instance where this chamber is preserved entire. In Brombach, and in other foreign abbeys, it has been replaced with one built in modern times, which, in that instance, is still used for the same purpose; but no example exists, as far as I know, of an early Scriptorium still remaining, although in some few cases, as at Furness and Fountains, its walls and windows are left.

When we consider how much we owe to the labours of the monks of the Middle Ages, who preserved and multiplied for us every fragment of ancient literature that we possess at the present day, as well Classic as Christian, it is somewhat lamentable to reflect that there does not exist a single instance of the preservation to us, at the present time, of the apartment in which those laborious works were carried on, and in which those inestimable treasures were guarded.

There are appearances in several abbeys about the space which intervened between the Scriptorium and the south wall of the Transept, over the Sacristy, which have led me to conjecture that a strong room, walled-up receptacle, or inaccessible hiding place, was here provided, probably for stowing away the valuables of the monastery in case of sudden attack; but they are not such as to warrant my asserting this as an ascertained fact.

I have now described the whole of the normal buildings of a Cistercian Convent, those, in fact, which surrounded the cloister; and to these on the present occasion I propose to confine myself. They constituted the principal domestic buildings of the earlier monasteries; and although in later times various other buildings were added to this central group, within the precincts enclosed by the outer wall, their situation is so various, and their destination is, in some cases, so doubtful, that to enter upon a description of them here would be to carry us beyond the limits usually assigned to a paper of this kind. I may, however, mention the nature and objects of some of these additional buildings.

The Abbot's Lodge, which I have reason to believe consisted originally of a single chamber over the kitchen, is often found constructed in later times, as a detached building, on the east side of the central group, and became an important structure of two stories, the lower one being his kitchen, furnished with its own fire-place, and the upper one his living room, both finished with some degree of elegance. It is found thus planned and situated at Fountains, Jervaulx and Netley. The lower apartment, or kitchen, was vaulted, and supplied with its own arched water-course, to carry off the kitchen refuse. Close to the Abbot's Lodge was his private Chapel; this exists still at Fountains and Jervaulx. At Furness his dwelling room appears to have been over his chapel, and his kitchen was an octagonal one adjoining the latter.

When the Abbot was a mitred one, and was Lord of the Manor, or possessed local jurisdiction, the Abbot's Hall was a building of considerable importance; we have noble examples of this structure at Fountains and at Furness, in both of which abbeys it formed, with the lodge and the chapel, an important group; in both cases the hall has been destroyed, but the whole of its foundation walls remain, and the plan of the building is still traceable and perfectly plain. At Fontenay there is a noble building, which appears to have been designed for a similar purpose.

The Infirmary was another building of importance; examples occur at Fountains, Furness and Croxden.

The Abbey-Mill, or its site, or traces of one or the other, are generally to be found on the stream which waters a Cistercian valley, and the resources of which were utilized in so many various ways; an examination and description of which might not be without its use even in the present day. We find it dammed up, diverted, divided, and directed to different parts of the convent, accordingly as it was required, as a water-power, as a fish-stew, for water supply, or for sanitary purposes. At Fountains its whole power was first utilized for the mill; issuing from which it was divided, as it

approached the convent, into four distinct portions by cut-water piers, and carried in different channels under and outside the whole building, by well-constructed arched tunnels, and open water-courses, some of which passing under the hospitium, the refectory, the kitchens, the great hall, and the Abbot's residence, supplied them with water, and others passing outside—and over which the NECESSARIA of the guests and the monks were constructed—carried off the sewage and refuse of the whole convent.

Similar examples of the manner in which the Cistercians recognized the value of sanitary principles in the selection of their sites, and in the utilization of their water supply, occur at FURNESS, TINTERN, BROMBACH, CROXDEN, JERVAULX, FONTENAY, and elsewhere. At CROXDEN and FURNESS the FISH-PONDS were on a grand scale, and are still distinctly traceable. At MAULBRONN the large reservoir, constructed by the monks for this and for milling purposes, was so much elevated above the abbey buildings, that after the dissolution of the monastery the latter became inundated, and when I visited it in 1833, the water covered the floor of the whole of the conventual buildings, to the depth of $1\frac{1}{2}$ feet.

The last building which I have thus hastily to notice is the ABBEY-GATEHOUSE; which, with its outer and inner arched entrance, its vaulted carriage-way, carrying the warder's chamber above, and its minor arch-way for foot passengers, was situated in the outer wall which surrounded and enclosed the precincts of the abbey; and contains many features of interest, in common with the similar gateways of other conventual and cathedral establishments. One of the earliest of these gateways, and a very magnificent one it is, exists still at KIRKSTALL Abbey, the whole of the Conventual Buildings of which appear to have been carried out at once, and completed according to the original design within twenty years of their commencement.

Remains of the outer WALL of the Convent, enclosing the whole precincts, are often to be found about ruined abbeys, even in this country, incorporated with modern restorations of it; and in some cases, as at FURNESS, it exists almost entire. Its preservation and reconstruction being due, probably, to the cause which maintains and perpetuates the picturesque irregularity of most of our walls and fences, and which is connected with the testamentary identification of property, and the nature of the legal tenure of land in this country. Thus it often happens that these noble buildings, in which the history of our National Architecture is perhaps more clearly recorded than in any others, and which were the store-houses, in a dark age, of all the treasures of learning, history, and literature of earlier times that we possess at the present day, have been suffered to fall into decay and ruin, whilst the fence wall that bounds their broad acres has been carefully preserved and upheld; for the arbitrary alienation, and transfer by gift of the property of the monasteries, at the time of their dissolution, although it supplied to its new owners a motive for the preservation of its boundaries, laid no legal obligation upon them for the maintenance of the buildings. Happily the present possessors of these valuable remains are beginning to recognize the moral obligation that the tenure of this property carries with it; and much has been done within the last thirty years to prevent further dilapidation and decay. It is to be lamented, however, in some cases, that these attempts have not been more intelligently directed; large sums having been ignorantly expended in rough works of reparation by bailiffs and factors, a portion only of which, properly applied, might have prevented the loss of valuable works. The instances which have fallen within my own observation of such losses which have occurred in the abbey-churches of this country, since my illustrations of them were published in 1846, are both numerous and serious.

Throughout the whole of the foregoing remarks, it must be borne in mind, I have been endeavouring to describe the plan of a Cistercian monastery as it existed in the middle of the 12th century.

Before the close of that century changes had been introduced in the plan of the church, which are too important to be passed over without notice. Whether it was Saint Bernard himself who set the example in his new Conventual Church of Clervaux or not, it is certain that many of the Cistercian churches built in the latter part of the XIIth century shew a development of choir, and an increase of chapels about their east ends, which is in striking contrast with those of the earlier churches of the Order. At Byland, commenced about A.D. 1170, and Abbey Dore, c. A.D. 1775, we have, as well as aisles added to both sides of an elongated choir, also a series of eastern chapels, along the whole of the east end. We find a similar arrangement at Ebrach, and Riddagshausen in Germany; whilst in France this development takes an apsidal form, with radiating chapels, current in that country, and of which the choir of Pontigny, added to the earlier Transitional choir, is a beautiful example. In England this fashion was also followed at Croxden, built at the close of the Transitional Period, where part of one of these circular radiating chapels remains to attest the real design. Still later we have in England also the noble aisled choirs of Fountains and Rievaulx, with the eastern transept of Fountains, resembling the nine altars of Durham Cathedral, built both, in the Lancet Period, in substitution and in prolongation of the earlier choir of the Transitional Period. And in the following Period we have the English examples of Tintern and Netley, with the enlarged square-ended choir, and the foreign one of Altenberg, in Germany, with its apsidal termination, bringing this increased development down to the middle of the thirteenth century. In all other respects the church and the conventual buildings of the Cistercians remained the same, up to this point of time, in their plans, and in their general treatment, as we find them in the commencement of the XIIth Century.

Can we draw no instructive lesson for works of the present day, increasing as they are continually in importance and in the means devoted to them, from the existence of this noble school of architecture in the Cistercian remains of Great Britain, and Continental Europe? For vigour and boldness of design, for excellence of proportion, and for simplicity, elegance, and purity of treatment, they are unsurpassed by buildings of any age or country; and a careful study of their numerous excellencies could not fail to exercise a beneficial effect on modern designs, by checking exuberance of ornamentation, and by the cultivation of a purer taste, delighting rather in form and outline, than in colour and in surface decoration.

The information which has formed the basis of the preceding description of the model plan of a Cistercian abbey has been derived as well from the documentary evidence contained in the chronicles enumerated, as from the existing remains of the following Cistercian Monasteries, the whole of which, with the exception of Clervaux and two others in France, I have myself visited.

RIEVAULX	...	Near	Helmsley	...	...	Yorkshire	...	England.
FOUNTAINS	...	„	Ripon ...	...	...	Yorkshire	...	England.
KIRKSTALL	...	„	Leeds ...	...	...	Yorkshire	...	England.
BUILDWAS	...	„	Wenlock	...	...	Shropshire	...	England.
FURNESS...	...	„	Ulverston	...	...	Lancashire	...	England.
CALDER ...	...	„	Ravenglass	...	...	Cumberland ...	...	England.
ROCHE ...	...	„	Rotherham	...	...	Yorkshire	...	England.
BYLAND ...	...	„	Thirsk ...	...	...	Yorkshire	...	England.
ABBEY-DORE	...	„	Hereford	...	...	Herefordshire	...	Wales.
MARGAM...	...	„	Neath ...	...	...	Glamorganshire	...	Wales.
CROXDEN	...	„	Cheadle	...	...	Staffordshire...	...	England.
SAWLEY ...	...	„	Clitheroe	...	...	Lancashire	...	England.

JERVAULX ...	Near Leybourn ...	...	Yorkshire	England.
BEAULIEU ...	„ Southampton ...	...	Hampshire	England.
VALLE CRUCIS ...	„ Llangollen ...	...	Denbighshire ...	Wales.
NETLEY	„ Southampton ...	...	Hampshire	England.
ST. MARY'S YORK	„ York	...	Yorkshire	England.
TINTERN	„ Chepstow ...	...	Monmouthshire ...	Wales.
NEATH	„ Neath	...	Glamorganshire ...	Wales.
WHALLEY ...	„ Clitheroe ...	...	Lancashire	England.
MELROSE ...				Scotland.
QUINCY	„ Tonnere ...	...	Yonne	France.
FONTENAY ...	„ Montbar ...	...	Côte d'Or	France.
PONTIGNY ...	„ Auxerre ...	...	Yonne	France.
CADOUIN ...	„ Sarlat	...	Dordogne	France.
CLERVAUX ...	„ Bar-sur-Aube ...	...	Aube	France.
FONTFROIDE ...	„ Narbonne ...	...	Aude	France.
THORONET ...	„ Fréjus	...	Var	France.
OBASINE	„ Brives	...	Correze	France.
VALLEMAGNE ...	„ Cette	...	Hérault	France.
VAUCLAIR ...	„ Laon	...	Aisne	France.
SILVANE	„ Vabres	...	Aveyron	France.
VAUX-DE-CERNAY	„ Chevreuse ...	...	Seine et Oise ...	France.
LONGPONT ...	„ Soissons ...	...	Aisne	France.
EBERBACH ...	„ Mayence ...	...	Nassau	Germany.
BROMBACH ...	„ Wurzburg ...	...	Bavaria	Germany.
MAULBRONN ...	„ Stuttgart ...	...	Wirtemberg	Germany.
HAILSBRONN ...	„ Ansbach ...	...	Bavaria	Germany.
EBRACH	„ Bamberg ...	...	Bavaria	Germany.
WALKENRIED ...	„ Nordhausen ...	...	Prussia	Germany.
RIDDAGSHAUSEN	„ Brunswick ...	...	Brunswick	Germany.
HEISTERBACH ...	„ Bonn	...	Prussia	Germany.
ALTENBERG ...	„ Cologne ...	...	Prussia	Germany.
HEILIGES CREUZ	„ Vienna	...	Austria	Germany.
CHIARAVALLE ...	„ Milan	...	Lombardy	Italy.

Mr. Sharpe then proceeded to describe in detail the different Cistercian Abbeys, the plans of which were exhibited on the walls of the lecture room, and to point out in what respects they corresponded with, or differed from, the model plan, explaining that the whole were drawn to the scale of a quarter of an inch to a foot.

Mr. G. E. STREET, Fellow, R.A., said: No one who cares much about English architecture, or who has thought at all about the Cistercian buildings of which we have so many remains in this country, can fail to endorse the high opinions expressed by Mr. Sharpe with respect to these great types of the best period of mediæval architecture; and it is a more than usually hard matter for an ordinary student of these monuments to follow, with any interesting or valuable remarks, a Paper on a subject which its author has so thoroughly studied, and on which, by his lucid *vivâ voce* explanations of the various structures he has described, he has left so very little to be said in the way of discussion which

will not be dry and tedious. I would, however, venture to say just a few words, remarking, first of all, upon the influence which the rules of the Cistercian body had, not only upon the plans of their own buildings, but also upon the whole architecture of their age. Mr. Sharpe has told us of the strict and systematic rules laid down by the founders of this Order against ornamental display in their buildings, against sculptured figures, and even against the use of stained glass. Almost the only exception to this rule was, that there might be a rood, which, I take it, was meant to be painted, not carved, like those painted roods which we see so often in Italian galleries, and an example of which we see in the Upper Church of San Francesco at Assisi, painted by Simone Memmi, as resting upon a beam across the church. That rule was so strictly enforced by the Cistercians, that I believe the human figure was never represented in their early buildings, and it may be viewed as a very practical protest against the lavish and luxurious use of ornamentation which was then common in all religious worship. It was, in fact, a sort of early burst of Puritanism which enforced the most extreme simplicity on the architect, which, coupled with the rigid adherence to the true principles of construction, which was common at the time, and doing nothing for the mere sake of display or ornament, has left us in these buildings what Mr. Sharpe has truly described as the best possible school for all students of English architecture. I venture to say that in some of the highest qualities they are equal to the purest Greek buildings. One is excessively proud that one can point to such works as these in England. The great Yorkshire abbeys, so many of which belonged to this order, are amongst the finest monuments of art, not only in England but I may say in Europe. I think, however, it would be rather hard to impress upon the young who, when he studies them, will probably do so as a pedestrian, that he should study these abbeys in their strict chronological order, as Mr. Sharpe advises. I would allow him to stop at the first he came to, and I would only advise him to fix upon such an abbey as Fountains, or any other of the great abbeys, and study and draw it thoroughly and exhaustively in all its parts before going on to another, and such study I am sure will be attended with happy results in his own work afterwards.

Mr. Sharpe has principally confined himself to descriptions of English examples of these abbeys, and I will not follow him farther on his own ground. Of the French abbeys, Citeaux, we know, is destroyed; but I, for one, would have liked to know more than I do about it, and the other great houses which must have followed its rule most closely, and specially of the most noble of all of them—that of Clervaux. We should then see better the influence of the mother-house throughout the order. One rule of the Order, of extreme importance in this matter, was that every abbot should annually attend the General Chapter of the Order, and from that we may infer how great the influence of the mother-house was likely to be. Take, for instance, Fountains Abbey, the noblest example in England, and I suppose the most perfect example of the buildings of a monastery that is to be found in Western Europe, and you have in them the most distinct evidences of the influence of the mother-house in the introduction of foreign features. The most remarkable of these are the vaults of the aisles, formed with barrel-vaulting at right angles to the nave vault. That is a feature peculiar to the centre and South of France, and it is an admirable system of construction, giving enormous strength to the main arcades. In like manner the narthex at the west end of Fountains has its arcades carried on coupled shafts, reminding one again of its origin in the beautiful shafted cloisters in the arcades of the same districts. At the same time it is very remarkable that, though the architects of these local institutions were allowed no opportunity of departure from the strict rules as to their ground-plans, which were laid down for them—rules which we notice particularly with regard to such small things as the provision of the passage or room next the transept, to which Mr. Sharpe has called our attention—yet, at the same time, it is rarely that you can put your hand

upon foreign features such as those which I have mentioned at Fountains, and which may be accounted for, perhaps, by the fact that among the earliest abbots of Fountains in the twelfth century, two had themselves been monks of Clervaux and abbots of Vauclair. I think also that it would not be difficult to prove that the monks of the order were not employed as the builders of their houses, or at any rate were not so invariably. One of the most beautiful of these structures is that at Pluscardine, near Elgin, and there can be no question, I think, that the same architect was at work there as at Hexham, which, if I remember right, was an Augustinian abbey. If you examine them, you will find the treatment of the north transepts of the two churches to be so alike that there can be little doubt as to their being the work of the same architect. The mention of Pluscardine leads me to the observation that we architects ought not to confine ourselves to the study of Cistercian buildings on this side of the border. The Scotch Cistercian abbeys are of singular beauty and interest. One of the most well known, as well as most beautiful, is that at Melrose, which is interesting as a later example than most others. Almost all the domestic buildings have unfortunately disappeared, but they were on the north side of the church, not on the south. Then there is Dryburgh Abbey, which is exquisitely beautiful, and much like Lanercost in its details, and Drendrenman, near Kircudbright; and, lastly, the most charming of all, New, or Sweetheart Abbey, near Dumfries, which has, as also has Pluscardine, the low central lantern which Mr. Sharpe mentioned; but as to the height, of which my experience does not quite agree with his, (he said, I think, that they were built one stage above the roof), but in all the examples I have seen of English lanterns they were finished with a parapet just above the level of the ridge of the nave-roof. The reason of this was that there was no need for a chamber for bells, for one of the most remarkable rules of the Order was, as Mr. Sharpe will remember, not only that there should be no tower for bells, but also that there should never be more than two bells, which were to be so arranged that one man could ring them by himself, a provision which one is sometimes inclined to envy, when one sees how belfries are used, and the architectural consequence of which is that you have only this low lantern at the intersection of the roofs, and no steeple.

Mr. Sharpe has mentioned the abbey at Heiligenkreuz, in Lower Austria, not very far from Vienna. That has very much the same arrangements of cloister, chapter-house, and lavatory, as the other great Cistercian abbeys. The nave and aisles are simple round arched work, built in 1140, but the eastern portion was all rebuilt in the fourteenth century. There is another fine Cistercian abbey at Zweth, in Austria, mainly of the fourteenth century, with an enormous apse, and chapels all round, the apse corresponding in plan and style with the great churches of Nuremberg, and possessing none of the usual characteristics of the Cistercian churches. There were four or five more established soon after Heiligenkreuz in that part of Europe, and, I believe at any rate, one very fine example at Czykador, in Hungary, with much the same arrangements. There are also some fine remains of these abbeys in Ireland, but though I have seen several I am not sure which were Cistercian. One of the difficulties one has to contend with when one visits an old abbey, unless one is well posted up, is to know precisely the religious order to which it belonged. There are some features described by Mr. Sharpe, rather as though they were peculiar to the Cistercians, which are common to all abbeys—such, for instance, as the triple entrance to the chapter-house, and the division of the chapter-house into nine or more bays. This, in truth, was an almost invariable arrangement. You see it, for instance, in St. Mary's Abbey, at York, where there are five divisions, and in the grand entrance to the chapter-house at Winchester Cathedral, where there are three. And both of these were Benedictine buildings. I ought not to forget, in speaking of foreign abbeys, to mention the first Cistercian house founded in Spain. I have the same sort of pleasure in talking about it which Mr. Sharpe has in talking of his discoveries at Furness, and at his French manufacturer's abbey. It

is true I made no discoveries, but yet I am one of the very few Englishmen who have seen it. I allude to the abbey of Veruela, built in a secluded and wild country, not far from Tarazona, and just on the lower slopes of the Sierra de Moncayo and Aragon. It is arranged very much on the plan of the abbey at Clairvaux, as far as the enclosure and the approach are concerned. M. Viollet le Duc has given the plan of Clairvaux, but I do not know how far the apparent completeness of its plan is warranted by what still remains. It seems to have been entirely surrounded by a wall or enclosure. At Veruela the whole of this enclosing wall still remains. About 200 or 300 ft. from the west front of the abbey church is a fine gateway in the walls enclosing the whole of the abbey grounds, which have circular towers at regular intervals. Then within the walls you find almost everything perfect. The church is of the twelfth century, and apsidal, and this was its original plan. The chapter-house and cloister are perfect, and one feature of great beauty is the lavatory opposite to the refectory in the south walk of the cloister. It is hexagonal, and a fourteenth-century addition, and in most of these cases the lavatory seems to have been added long after the cloister was built, just as if it had not been one of the early rules of the Order to wash hands before and after meals. At Zweth the lavatory is hexagonal; at Heiligenkreuz nine-sided; at Maulbronn similar, and there seems to have been one at Clervaux also, polygonal, and all of them are in the same position. It is somewhat curious that one of the few examples of figures in stained glass is to be found at Heiligenkreuz, in the windows of the lavatory, where there are full length figures of the founders of the church; though in the church itself the original glazing was nothing but grisaille.

With regard to the advantages to be derived from the study of this subject, I can conceive nothing of such good discipline to us, as architects. In the first place, it is a school of great simplicity. There is hardly any carving, even of foliage; and it is reasonable to suppose that an architect who could draw a really good moulding would prefer doing this to employing some one else to do bad carving; in that respect, at any rate, the study of Cistercian buildings, might be an advantage to most of us nowadays. More than this, I cannot help feeling. To my mind, there is much of what I must almost venture to call holiness about this exquisite work. It is not, I believe, too enthusiastic a thing to say that, in the presence of works of such transparent purity and simplicity one cannot help feeling really elevated; and the art which can do that is art which is worthy our deepest study and reverence. I think the magnificent guest chamber at Fountains Abbey, in which the ribs of the groining are merely chamfered, is one of the most impressive and beautiful things I ever saw. A building of, I believe, nearly 300 ft in length, and 40 or 50 ft. wide, it is one of the most glorious things, and yet it is absolutely without architectural display or pretentiousness; it owes its good effect to its beautiful proportions. In conclusion, I must say that I have never experienced more pleasure than I have done in hearing Mr. Sharpe's paper to-night. I hold that gentleman in the greatest respect for his endeavours to teach us what English architecture is. His work, which appeared twenty-five years ago is one of the greatest architectural works we have, and one for the publication of which he deserves the greatest possible respect at our hands; and I am delighted at having the opportunity of thanking him personally for the great service he has rendered to our profession.

Mr. JOHN P. SEDDON, Fellow.—I beg to second the vote of thanks to Mr. Sharpe, feeling, as I do, very thankful indeed to him for what he has put before us in so clear a way. When we think of the trouble he has taken in preparing these numerous plans, we owe him exceeding thanks. We have the benefit of those labours, and the paper opens out suggestions which might be discussed for many hours. These abbeys, though they have this general coincidence in the main features, are nevertheless so varied in detail, and each group in different parts has been subject to so many local circumstances, that fifty papers might be read upon them. I would particularly call attention to the group of which Tintern is

the type, and others which are not so well known as they ought to be—such as Llanbourg, Margam, and Neath. Many of them are nearly destroyed, but it would be a valuable study for young men to try and restore in idea what some of them were, especially that of Margam, which has the striking peculiarity of a chapter-house more beautiful than even that of Westminster. But there was one abbey in particular I would mention, Crom Hir, in Mid-Wales. I shall hardly be believed when I say the nave was double the length of Fountains, and consists of twenty-four arcades of the most magnificent character, five of which have been removed bodily to the church of Llaidloes. These consist of octagonal piers, with a triplet of small shafts upon each side of the octagon, and with beautiful capitals and rich arch moulding.

Mr. EWAN CHRISTIAN, Fellow.—I will not add a word to what has been said about these buildings. I have studied them myself with great delight. All I would do is most emphatically to back the advice Mr. Sharpe has given to young architects, that they should also study them with the greatest zeal. With their knapsacks on their shoulders, let them visit the Yorkshire Abbeys, and I am quite sure they will come back wiser men than they went, and with a store of ideas such as they could not gather from any other class of ecclesiastical buildings. Mr. Sharpe has not said one word too strong as to the beauty of the mouldings. Nothing can be more beautiful than the moulded work of the Cistercian Abbeys. There is nothing in this kind that I know more beautiful than the mouldings of the east end of Rievaulx Abbey Church—mouldings as beautiful as it is possible for the human hand to work. It is a good deal the fashion in the present day for people to go abroad to seek for the beautiful in architecture, but my advice to young architects would be to take the English abbeys first, study them carefully, and afterwards visit those on the continent. They would find not only beautiful architecture, but beautiful scenery, and I know no more refreshing or delightful way of spending a summer's holiday than to ramble amongst them, and especially those in Yorkshire and the North.

Mr. W. WHITE, Fellow.—I will not now stop to argue the question of the influence which these buildings have had upon our village architecture throughout England, great as has been its effect even in the formation of the national character. I would only add to what Mr. Christian has said, that if we want to go from England for our studies, we cannot do better for our first expedition than go to Ireland, There is one point I think Mr. Sharpe would like me to call his attention to, with regard to the uses to which that, which has been called the narthex, the vestibule at the west end of the church, was appropriated. Mr. Sharpe considers the use to have been principally for penitents. It occurs to me that it has some connection with what I have found to be the uses of the somewhat similar constructions at Durham and Ely. Having discovered last year what these uses were, and having given the result of my investigation to the Society of Antiquaries, the evidence will be seen when published, but it may interest Mr. Sharpe to hear the conclusions I came to about them. It is manifest from the architectural evidence alone, and it is borne out by traditional evidence and the records which I have been able to consult, that the narthex, or Galilee of Durham, was built for the Bishop's Consistory Court. It was built external to the cathedral, while nearly all others had their courts inside. This was built outside, because it was necessary to have a secular court as well as an ecclesiastical one, the bishop who built it having been made by the King his chief justiciary. I cannot help thinking that in these abbeys the priors had some secular jurisdiction* over the people apart from the government of the monastery itself, and that it was the same with respect to some of the Continental cathedrals, for in some of these, especially at Veiziley, M. V. le Duc was much puzzled to account for them.

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* The fact to which Mr. Sharpe subsequently referred bears out this view. The erection of the large Justice Hall at Fountains was *at a later period*, when the vestibule or cloister at the west end of the church would no longer afford sufficient accommodation.—W. W.

Rev. E. L. CUTTS, B.A.—I beg leave to offer my thanks to Mr. Sharpe for having given the results of his many years' study of this subject in the very able paper with which he has favoured us, to which I—having given some attention to the subject for some years past—have listened with the greater pleasure and with the greater sense of its value. There are one or two points with reference to the appropriation of certain parts of these buildings, on which I would venture a remark or two. For instance, the cell-like building between the transept and the chapter-house, which Mr. Sharpe supposes may have been used as a dead-house. I think, looking to the fact that in those days burial took place so speedily after death, it is hardly probable that a special apartment of that kind would have been appropriated as a dead-house. It was, I suppose, the custom to remove the body of a deceased monk at once into the church, where it "lay in (a kind of) state" until the interment. The passage on the other side of the chapter-house was, I believe, used as a passage from the cloisters to some important place or building on the east side, but not as an entrance into the cloister for visitors. I believe such persons would hardly have been admitted at all into the cloisters. I would suggest that it was used by the Abbot, whose house was so commonly situate at the east end of the building, as his entrance into the cloister, and through the cloister into the church. Again, with regard to the long building which forms the west side of the cloister court, unless Mr. Sharpe has good authority for considering it the Hospitum, I would suggest that part of the cloister buildings was otherwise appropriated. By some it has been thought to have been offices, cellars, store-rooms, and the like; others have thought that it was the building appropriated to the Conversi; these Conversi being a kind of lay brothers, servants, artizans, and the men who did the actual agricultural labour for which the Cistercians were so famous. Perhaps the under croft was used as store-room and the upper story as the lodging of the Conversi. Then again, as to the general plan of the church: Mr. Sharpe throws out the idea that the square east end was an arrangement peculiar to Cistercian buildings; but the model house at Clairvaux (the existing building there being older than that of Citeaux), had a circular apse with an aisle round it, at the east end, as is also the case with some of the later churches in England and on the Continent, *e. g.* Beaulieu in Hampshire, in addition to those whose plans are exhibited here by Mr. Sharpe. May not the explanation be simply this, that Norman Cistercian churches have apses because it was the Norman fashion of building, but that Cistercian churches of later date have square east ends, because the fashion of apses went out together with Norman architecture. Then, with regard to the narthex at the west end: I would ask whether it is as common a feature in English Cistercian churches as Mr. Sharpe supposes? In France, Violet le Duc tells us, it *is* a chancel, and is *not* a Cistercian peculiarity.

Mr. FAIRLESS BARBER, F.S.A., mentioned that a visit was about to be paid by the Yorkshire Archæological and Topographical Society to Kirkstall Abbey, to which any members of the Institute would be heartily welcomed. Yorkshire, he said, was proud of her numerous examples of Cistercian Abbeys, for the study of which every facility was offered by their proprietors.

The PRESIDENT expressed his regret that the lateness of the hour warned him that this interesting discussion must be brought to a close. He was sure all present were sensible of the obligations which they owed to Mr. Sharpe for the able manner in which he had treated a report so full of antiquarian interest. He now begged to put the vote of thanks which had been proposed to Mr. Sharpe, which he was sure would meet with an unanimous response from all present.

The vote of thanks was passed by acclamation.

Mr. SHARPE, in acknowledging the vote of thanks for his paper, expressed the pleasure which the revival of his recollections had afforded him in bringing the subject before the Institute. He explained, in regard to what had fallen from Mr. Street, that in his reference to the pointed transverse

barrel vaults of the side aisles of FOUNTAINS Abbey, he had accidentally touched upon a very interesting and important fact in illustration of the close connection that existed between the designs of French and English work in these Cistercian plans: it is quite true that this vaulting is peculiar to FOUNTAINS Abbey in this country; but in France there is another example of it, and the only one that he knew of, and that occurs in the church of the Cistercian abbey which bears the name of FONTENAY, the French FOUNTAINS in fact, for the origin of the word is the same. This abbey of FONTENAY, moreover, we know to have been commenced in the year 1139, and finished and consecrated in the year 1148; and it remains in even a more complete state, as regards the Church, Cloisters, Chapter House, and Fratry, than FOUNTAINS itself, having been appropriated to the purposes of a paper manufactory, and being occupied at the present time by the well-known family of Montgolfier, descendants of the inventor of the balloon, who take the greatest care of the buildings, and pride in them. But here it must be also explained that this convent was founded by an English ecclesiastic, Everard, Bishop of Norwich, who was buried there; whether, therefore, the use of this peculiar vaulting was an English importation into France, or a French importation into England, may still remain a moot point. A comparison between the other features of the two buildings is also extremely interesting, almost simultaneous as they were in point of construction. In speaking of the absence of the representation of the human face or figure, I meant to limit this remark to the works which were constructed during the first two centuries of the existence of the order: the instance referred to was probably of later work. The Refectory invariably stands north and south in Cistercian abbeys,—in other abbeys usually east and west.

CLERVAUX is one of those abbeys which I have not seen, and which, as it is a house of detention for criminals, it is very difficult to get into, I mean for an architect. It has been much cut about and modernized, to suit the purposes to which it is now appropriated, and I believe that very little of the original work is left. It is not the original building, in which in all probability there was no apse, and if the apse shewn on the plan really formed part of the church re-built by St. Bernard, which I am inclined to doubt, it was probably the first Cistercian church in which it appeared.

No doubt there were apartments used as halls of judgment, as Mr. White remarks, in abbeys where such jurisdiction was exercised by the abbot; but I doubt whether this was the use to which the narthex was applied. At Fountains, for example, the remains of both the narthex and the abbot's hall of judgment still exist.

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